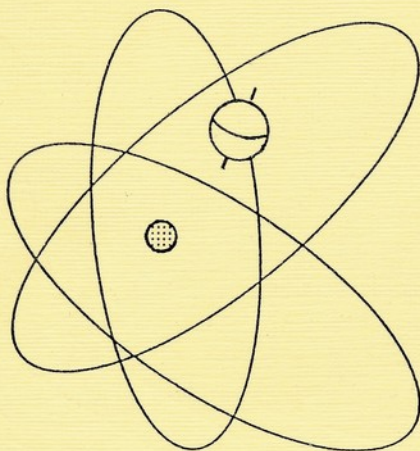


Wind Controlled Climate

Doctoral Thesis

by

Hans Jelbring



Paleogeophysics & Geodynamics
Stockholm University
S-106 91 Stockholm, Sweden
1998

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*The function of Nature
is independent
of our understanding
how Nature works*

Front cover:

*Picture symbolizing the influence on Earth's climate
both from microcosmos and from macrocosmos*

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ABSTRACT

Climate change is analysed, seen from a wide perspective. The problem involved in climate change has been subjectively defined and a solution is sought. Limiting factors as the incomprehensibility of systems, the errors in proxy variables, the inadequacy of general circulation models and lack of interdisciplinary research are taken into account.

A basic simple energy flow model, is proposed to identify the most important energy flows in Earth climate system and subsystems that control these flows. Observational evidence is discussed in relation to identified and defined subsystems, in relation to selected important processes and finally relating to results from simple models.

It is concluded, that several processes controlling climate change are involved, but that different processes are dominating in different time scales and also in different hemispheres. Thus, it is strongly suggested that climate change, over the longest time scales, is dominated by changes in atmospheric mass. Global cold climate is proposed to develop primarily as a consequence of increased infrared emission from the northern hemisphere into space. Global energy storage is proposed to be controlled by global land-ocean distribution and to be dominated by sensible heat storage in the southern hemisphere oceans. Deglaciations are proposed to occur as a consequence of large scale interhemispheric exchange of Atlantic Ocean water, cold northern Atlantic water being replaced by warm southern Atlantic water. Interglacials are proposed to be sustained by large scale atmospheric energy transfer from the southern hemisphere to the northern hemisphere during northern hemisphere winters, a process that is switched on and off by unknown factors.

Of special interest, is northern hemispheric dominance of infrared energy emission and the southern hemispheric dominance of energy storage. These energetic inequalities between the hemispheres, establish a theoretical basis to understand why eccentricity variations can introduce large amplitudes in the 100 ky cycle, despite the fact that each hemisphere on a yearly basis, receives about equal amounts of energy by insolation.

Hemispheric relocations of stored sensible heat in the atmosphere and hydrosphere, are suggested to dominate glacial-interglacial climate change on Earth. Two climate subsystems have been identified as contributing to energy relocation making it possible to describe the energy exchange as a cause and effect relationship. Some of these relocation events are strongly suggested to be triggered by tidal effects.

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PREFACE

The questions concerning the creation of the Universe, Earth, life on Earth and of the human race, have always been of interest to us, probably since we could formulate the question, who started all this? Some people just seek an answer and they accept the best one they can find, not because they seek the truth, but because they wish to avoid the threat of mysteries of unexplained phenomena.

Some people do not, they get challenged and want to explore, step by step. Each question that has no answer is a challenge. I imagine it works like the forces that drove men from old times to discover new territories on Earth, to move to places where humans had never been before..

I still remember it so clearly. In 1973, I read an article about Galilei and his observations of sunspots, and like a sudden clear insight, it was quite obvious to me, that we did not understand more today, about the processes causing sunspots to develop on the Sun than Galilei did 350 years ago. From that moment my wish to find out the answer of that riddle has never ceased. It has led to many more questions, relating to the most diverse types of phenomena in nature, from being a sporadic amateur interest, to profoundly influence the way I have chosen to live my life. Today, I am convinced that the whole picture of planetary interactions have to be solved before we can understand the cause-and-effect relationships in climate change on Earth and the mystery concerning sunspot generation.

This is the background leading to this doctoral thesis, which to me, means that other people can share parts of my discoveries and maybe use them on their own journeys into the fascinating realms where knowledge and mysteries meet.

PART I

Painting the picture

How can human beings – living only for “a second” in the geological time scale – comprehend phenomena that we have never experienced and never will experience, and, furthermore, happen on an Earth that was very different from the one of today.

1. Space and time

The history of Earth is written down in the geological records. Mostly the language in the records is as poorly known as is the grammar. The sentences don't seem to make sense even if the words sometimes can be understood. Still there is a message waiting to be deciphered but often it seems a hopeless task.

Picking up a shell of a clam 4,000 m above sea level in the Himalay mountain range might just be an odd experience, creating a vague wonder: Who brought it from the sea?

When Titanic hit the iceberg, the object causing the disaster would disintegrate and in time no one could claim that this particular object caused Titanic to sink. Before the ship sunk it had passed millions of small animals, zooplanktons, the minute carbonate tests of which constitute the potential building blocks of a future mountain range.

The decimeter scaled sedimentary layers in the French-Italian Alps looks like a decoration, sometimes vertical, sometimes folded making impressive pattern seen from a distance. Maybe they were created for filling the purpose of art, shaping fantastic cliffs after rain and rivers have eroded the less resistant layers.

Looking out through the window we see fertile fields in three directions and a lake at a distance of 500 meter. 2,000 years ago our house was situated on a small rocky peninsula. During the Younger Dryas period 12 thousand years ago, a layer of ice one kilometer thick covered the place where I now sit writing, which at that time was situated more than a hundred meters below sea level.

Life forms and the surface of earth is intimately related in many areas of the world. Paradoxically, it is life in the oceans that has produced the building material to many land areas and mountain ranges. The small carbonate and to a lesser degree silicate debris (tenth or hundredth of a millimeter each), left mainly from phyto- and zooplankton, is what makes up the basic material in the Himalayas, the Alps and the Grand Canyon areas, just to mention some places. Let us for illustrative purposes create scenarios of Titanic's future fate.

Scenario 1: The sediments at the position of Titanic's burial place will grow at a rate of about 2 cm per 1,000 years meaning that it will take about 3 million years to cover the ship completely in sediments. The solidification of the sediments will require some more million years. Plate motion and/or tectonic uplift will transfer Titanic to a position above the sea level within 10-200 million years. After such a period Titanic or parts of it, might be found in a future “Himalaya” or a future “Grand Canyon”, maybe cracked by more or less severe folding events.

Scenario 2: The position of Titanic is such that it will be subducted into the interior of Earth (at a 95% confidence level) within 200 million years and no one

will ever see any identifiable parts of it at a land or a sea position after it has been totally covered by sediments within 3 million years.

Scenario 3: This scenario also takes into account chemical corrosion and biological activity by benthic organisms. The rate of sedimentation is so slow that all common metals will corrode totally. Pieces of wood will be attacked by bacteria and by higher benthic organisms. Nothing of wood material is expected to be left. Silica glass is also expected to corrode but certain types of ceramic material might survive. The tourist in the future "Himalaya" or "Grand Canyon" might find the gold bars, from within Titanic's safe together with some porcelain, wondering how they could become totally integrated parts of a solid rock.

What have all this to do with the title "Wind controlled climate". The message is simple. The interaction between biology, chemistry and physics, in forming and shaping environments, is very complex. The geological records found in all types of sediments and organic fossils are overwhelmingly abundant but the interpretation of different records are not straightforward. Neither are the interpretations of instrumental records during the last couple of hundred years concerning climatic and meteorological data. The theoretical understanding of climate is far from complete. The main problems concerning climate change are unsolved despite tremendous efforts in the scientific community during the last decades.

A way to reach towards a solution, or at least a partial one, might be to restate the problem. By shifting the mental focus from a single forcing variable (i.e. insolation) new ideas might emerge. Atmospheric winds are suggested as a variable not only dependant of solar effect variations. The approach might seem inappropriate because, since it is generally held that winds are caused by atmospheric temperature gradients and that these are a function of insolation variations. Nature shows us that this "knowledge" is not solid. Voyager II registered jet winds in the Neptunian atmosphere, stronger than the Earthly ones and lasting less than days. The solar insolation to Neptune is approximately one per mille of the insolation reaching Earth.

Thomas Huxley was a disciple of Darwin and a vigorous defender of his hypothesis regarding natural selection among species. He once stated: "*A wonderful theory, killed by one, evil, ugly fact.*" This statement will be the motto of this thesis. Observed facts, preferentially from independent scientist, will not be rejected regardless if they are understood on a rational basis or not.

2. Is climate variability a problem?

Since all lifeforms are more or less dependant on the amount of rain, groundwater, sunshine, extreme temperatures, supply of food etc, there is no wonder that climate always has been considered an essential factor of human life. The daily and yearly variations of temperature have never been hard to relate to the existence of our sun, although the question whether the sun revolves around Earth or vice versa was a scientific problem just a few hundred years ago. The temperature variations at different latitudes could easily be understood after the recognition of Earth's spherical shape.

By climate change we don't mean "normal" temporal or latitudinal changes in temperature and precipitation. We mean anomalous deviations from these or long term changes that often challenge the survival of species living in

established habitats. Many (human) migrations all around the world have occurred during the last 10,000 years, especially since agriculture evolved as a major method of producing food. Most of human migration have occurred because of climate change. Still, climate change during the last 10,000 years have quantitatively been of a minor character, comparing to what occurred before the Holocene.

During early Holocene time large parts of Sahara and the Arabian peninsula were fertile with rivers flowing where deserts prevail today. The temperature optimum in Holocene (pronounced in Scandinavia) probably occurred then. The word probably is used, since it seems unlikely that the yearly mean temperature in Scandinavia will once again reach 2°C above today's average. One reason is the cyclic nature of long glacials and shorter interglacials, that has repeated itself at least 5 times during the last million years. The Scandinavian climate is probably soon to enter a more harsh phase, although it is controversial if this interglacial will last 1, 10 or 25 thousand more years.

Expanding the time horizon, it should be noted that glacial cycles in mid-latitudes are not common in the climate history of Earth. About 2.5 million years ago a prominent shift in climate occurred. This is recorded (among other sites) in Chinese loess originating from arid environments. Loess-fertile soil sequences have occurred around 40 times since the onset of this shift in climate. No loess has been found at this location before that time. Each cycle corresponds to a more or less severe cooling of the northern hemisphere.

About 2.5 million years ago the first severe glacial periods in the northern hemisphere are claimed to have happened according to Funder, (1996). He has investigated an 80 m thick sediment section at Cape Copenhagen 82°N, 23°W in Greenland. The top and bottom parts have settled from glacial conditions. The intermediate layers range from arctic, subarctic and boreal climate conditions. The latter type of climate indicates a far warmer climate than the one prevailing today.

Moving further back in time, it is claimed, that the land based glaciers in Antarctica have been cold-based glaciers since 10-12 million years, indicating that no U-shaped valleys have been eroded on Antarctic inland areas since then. Still, there are plenty of such valleys underneath the ice cover. Thus, Antarctica developed its main inland glaciers earlier than 10 million years ago when the glaciers on land were still wet-based.

In a showcase at the unit of Paleogeophysics & Geodynamic, SU, there is a piece of a petrified beech trunk weighting about 30 kg. The specimen is in excellent condition showing a number of holes and even shell from *Teredo navalis* indicating a partial submergence in water during its acquaintance with hungry animals. This piece of petrified wood, was brought from Sýmucur Island, Antarctica by Möerner, 1989, and can be dated to around 52 million years BP (Möerner, N.-A., 1991). The latitudinal position of Antarctica has not changed dramatically since early Tertiary time. The modern Swedish beech need a minimum mean annual temperature of around 6°C to survive and *Teredo navalis* presumably demands even higher yearly mean temperatures to survive.

Severe glacials seem to have been lacking during a period of at least 200 million years before modern time. Up to now variations in "climate" with

temporal changes from days to two hundred million years have been mentioned. The scientific community is searching for facts that can explain the variations in life conditions on Earth during its existence. The search has mainly been focused on one physical variable, the energy input to the atmosphere and hydrosphere of Earth.

The main physical processes that modulate the energy input to Earth besides its rotation and the period of revolution of Earth around the sun, depend on celestial parameters and albedo. With this insight, Milankowitch, (1941), tried to explain climate variations as a consequence of eccentricity, obliquity and precession, all of which modulate regional and global insolation.

At this point it will be stated that there exists an abundance of observational climatic variables or "proxy" variables that indicate periods or rather quasi periods from weeks to millions of years. There are also strong reasons to question the hypothesis that variation in insolation are the only important causative agent affecting climate, which will be motivated later on.

The main viewpoints regarding climate change research can thus be concluded as: Climate has mainly been seen as a function of one single variable which is insolation. This variable has been claimed to depend on celestial parameters on one hand (Milankowitch variables), trace gases on the other hand (Greenhouse effect) and solar energy output variations on the third hand. What have been omitted totally or almost totally, are changes in Earth's infrared effect emission and the factors controlling it. This is a central issue in this thesis and the title of the work indicates the author's opinion that the atmospheric wind system is essential for the temperature balance of Earth.

Moreover, the author is persuaded that there exists a basic problem with the scientific understanding of climate change. Despite tremendous manpower efforts and technical support, both in the field and in the laboratories, there is a lack of identification of dominant physical processes that cause the climate change. Primarily it concerns cyclic or quasi cyclic changes between hundreds to millions of years but it is also applicable in the temporal range of weeks to hundreds of years.

The author means that many subsystems that govern the dominant components of climate change (energy flows) are not understood today. In this respect we could as well consider the climate change a response of God's will which has been the common approach for human beings during thousands of years. To do so is a way for us to declare that these phenomena are beyond our understanding and power to influence. A scientific way to express the same insight could be: *"This (climate) system is incomprehensible at the level of today's scientific knowledge, mostly depending on its vast complexity."* A question could be proper to ask. *"What type of methods are available to gain knowledge and understanding of incomprehensible systems so they might be able to turn into comprehensible systems in the future?"* An awareness about the limitations of scientific methods might be essential in unlocking the riddles of climate change. Incomprehensible systems are treated in II:10.

3. Philosophy and system thinking

In mathematics, the axioms and the hypothesis are stated. The rules for the operations are well defined and fixed. By skilled manipulations the hypothesis can be proven. Later on, the proven hypothesis might be considered an axiom

in a new hypothesis. In this way a logical structure is built where proven hypothesis become cornerstones in new structures. The system is closed in mathematics, meaning that all relevant variables are known as well as the rules for their interaction. Everything will work fine as long as the initial axioms actually are "true" in a here undefined sense.

Theoretical physics works like mathematics but here the mathematical formulas are models of real phenomena. There will always be limitations concerning the validity of the model. The objective is to work with a closed system. No unknown subsystems or undiscovered fundamental laws should affect the derivations and calculations. But this wish can only be accomplished in a defined physical surrounding where the potentially unknown factors can be proven to have minor influences. Results from theoretical physics are often considered as true when confirmed by observations in the real world.

In both mathematics and theoretical physics the results depend heavily on synthesis, moving to the final result by knowing the parts of the system and the rules that apply to their interactions with each other. In experimental physics (as well as in chemistry, biology and other applied sciences), a hypothesis can be proven in a scientific way without understanding how parts of the system function, or exactly knowing the rules for their interaction with each other. By scientific convention a proof of a hypothesis should contain:

- Construction of a closed system
- Applying input signals to the system
- Observing the output signals
- Describing cause and effect relations between variables that are valid at a certain confidence level.
- Repetition of the experiment until the acquired confidence level is reached.

A result from a specific scientist is secured by the possibility for another scientist to repeat the experiment. Experimental physics can thus gain information from incomprehensible systems if they are closed and the experiment is possible to repeat. The application of results from laboratory experiments to conditions in nature will sometimes fail. What is controlled (a closed system) in a laboratory is often uncontrollable (not a closed system) in nature.

In geology, biology, palynology, geochemistry, biochemistry, biophysics, oceanology, astronomy, meteorology etc, the scientists are often confronted with systems that are incomprehensible, not closed and where experiments are not repeatable. None of the above mentioned methods to prove a hypothesis seems applicable to many of the systems concerning climate change. To complicate the problem solving, a specific climate change problem mostly involve subsystems concerning several of the disciplines mentioned above, introducing organisational problems.

Do these circumstances make it impossible to prove hypothesis concerning climate change? *The answer is no, but the task is complicated and often very elaborate.* If climate change is accepted to be an incomprehensible system, or rather many combined ones, there is only one main way to establish knowledge. Since nature arranges the experiments, the only way to gain first hand information and understanding of its incomprehensible processes, is to

observe the results of its experiments. This can be a tedious work.

If climate change is considered a comprehensible system in the sense that all the main physical processes acting in the system are known and its interactions with each other are understood and can be described in physical terms, then there is an alternative. In this case the processes can be simulated in a computer and the results can be useful. This is today done in what is commonly called GCM:s (General Circulation Models). This approach to solve the main problem with climate change will in this work be rejected as an adequate scientific method. The main argument is that the climate system is incomprehensible and thus the quantitative errors of the models are unknown. A risky model type to believe in are GCM models since they should include all incomprehensible subsystems in nature and related interactions.

The reason why the incomprehensibility of the climate system has been stressed in the above text is that scientists seldom mention this basic fact in their work. It actually means that the scientist don't know if there exist unknown physical, biological, chemical or other processes that can affect the results in an unknown way and to an unknown extent. If they were more conscious about the incomprehensibility of systems, they would very often have to point out limitations in interpreting data associated to them. Admitting this, often means that extra work has to be done before conclusions can be proven and generally accepted, or even that the desired conclusions should not be claimed at all.

Since the complexity of subsystems often are very high, information from the same data set (for example from an ocean drill core) can provide quite different conclusions by different scientists. The reason might be that experts from different disciplines treat the problem from their own professional knowledge. Their different conclusions can depend on the fact that all processes working in the system actually are not identified and thus the main processes might be poorly understood. Different scientist might also defend their own preferred hypothesis. This has sometimes been a dilemma in the scientific community for several reasons.

PART II

Subsystems, processes and models as tools for analysis

In this part important topics of very different types are treated. It is not needed to read them chronologically. It might be best to read a specific part when there is a need of relevant information. An overview of and comments to the topics treated in part II are found in III:2.3–6. Abbreviations will be used in the text without explanations. The abbreviations used in the text are listed below:

AIS	Ancient Incomprehensible System
ASI	Atmospheric-Space Interface
CaCO ₃	Calcium carbonate
CIS	Commandable Incomprehensible System
CS	Closed System
°C	Centigrade
¹³ C, ¹⁴ C	Carbon isotopes
DSDP	Deep Sea Drilling Project
E	East, Eastern
ENSO	El-Niño Southern Oscillation
ETP	Insolation effect (often at a certain latitude)
GCM	General Circulation Model
GIN	Greenland Sea, Island Sea, Norwegian Sea
HDF	Horizontal Density Forcing
IS	Incomprehensible System
ISE	Interhemispheric Subsidence Effect
ITCZ	Inter Tropical Convergence Zone
K	Kelvin
L	Mixing Length
LGM	Last Glacial Maximum
LTI	Longitudinal Tuna Index
MLT	Mixing Length Theory
MIS	Modern Incomprehensible System
MPH	Mobile Polar High
MSCE	Maximum of Southern Caloric Equator
N	North, Northern
NH	Northern Hemisphere
NISE	Northern Interhemispheric Subsidence Effect
ODP	Ocean Drilling Project
¹⁸ O	Oxygen isotope
Pa	Pascal, pressure unit
PDB	Pedee belemnite (standard)
QBO	Quasi Biennial Oscillation
S	South, Southern
SEC	South Equatorial Current
SH	Southern Hemisphere
SIS	Solid Incomprehensible System
SMOW	Standard Mean Ocean Water
SST	Sea Surface Temperature
TIC	Total Inorganic Carbon
TOC	Total Organic Carbon
W	Watt
Wm ⁻²	Watt per square meter

1. Earth's energy balance

1.1. Areal distribution of solar effect

A relevant question is; Are there any subsystems that can cause climate variations, quantitatively more important than the unquestionable insolation variations? Consider a crude model where the Sun is assumed to be at a constant distance and where Earth's axis is assumed to be perpendicular to Earth's orbital plane. Also look at Earth from the Sun and describe Earth's surface as percent of the circular disk that receives constant insolation from the Sun. There are reasons to believe that the output would vary even if insolation is kept constant. The functional relation is described by the following sequence:

Constant effect	Modulation of input	Energy accumulation	Modulation of output	Variable output
--------------------	------------------------	------------------------	-------------------------	--------------------

If some of these quantities are essential, it might lead to the identification of some important subsystems. Insolation variations can be taken into account at a later stage. This is a simplification of the problem involved in climate change but formulating it does initiate an investigation along a new path.

Table 1 shows the areal percentage of land, oceans (water surfaces) and snow or ice cover as seen from the Sun during 3 stages, an assumed ice free world, Holocene and during LGM.

Table 1. Areal distribution of solar insolation (in %) as a function of major climate regims.

	northern hemisphere			southern hemisphere		
	land	sea	snow	land	sea	snow
Ice free world	18.4	31.6	0.0	8.7	41.3	0.0
Holocene	18.0	31.1	0.9	7.9	39.2	2.9
LGM	13.2	27.7	9.1	7.8	35.6	6.6

Oceans and seas cover 70.8% of Earth's surface but they receive 72.9% of the solar energy. This is because land areas are proportionally situated at higher latitudes than the oceans. Of more interest is the hemispheric differences between insolation on land, oceans and snow. During both Holocene and LGM, SH oceans absorb more solar effect than NH oceans. The over land insolation excess during Holocene in NH is almost going down to half the value during LGM. Also note that solar effect on snow covered areas is larger during LGM than during Holocene.

The above quantities are calculated by assuming that NH is covered by snow and ice from the pole to 70°N during Holocene and to 45°N during LGM. The equivalent latitudes for SH are assumed to be 60°S and 50°S. The percentages in Table 1 is calculated by measurement from an atlas and the error should be less than 0.5%.

1.2. Energy storage in the atmosphere and oceans

The cause for climate change has often been attributed to variations in solar insolation and varying albedo. Few works have been considering varying energy storage in the atmosphere/ocean systems and the potential existence of a time varying resistance for infrared effect leaving Earth. If energy conservation is taken for granted and energy from the interior of Earth is neglectable, the nonreflecting part of solar energy has to leave Earth sooner or later. This boundary condition does not forbid the temperature of Earth's surface to vary. One example is given in section II:7 where it is shown that the surface temperature of Earth is a function of atmospheric surface mass density, all other variables kept constant.

But even with a constant atmospheric surface mass density, a constant insolation value and a constant albedo the surface temperature might show temporal variations. Let for example the global mean surface winds increase their speed. The result will be a faster transfer of water bound energy to the atmosphere and into space. If the surface winds stay stronger for a long time, the ocean surface will cool despite constant solar effect and albedo. The ocean will cool until the evaporation effect at the lower temperature is equal to the evaporation effect at the initial temperature. At that stage the emitted effect into space per unit area is constant at the original level again but the ocean surface temperatures are lower. The changes between states also induce transient energy flow and temperature variations.

Thus, surface temperatures and energy storage in the terrestrial system depend on the dynamic situation in the system. Here it is not told what caused the surface winds to increase in strength. This issue will not be elaborated now but it should be seriously asked whether winds caused temperature to fall or falling temperature caused winds to blow.

1.3. The simplest energy balance model

The simplest model to calculate the surface temperature of Earth is based on Stefan Boltzmann's law of radiation. The basic assumption is usually to assume that solar energy is evenly distributed over the surface of earth.

With this fair but unrealistic assumption the Earth mean temperature seen from space is given by,

$$1360/4 = 5.67 \times 10^{-8} T^4 \quad (1)$$

which gives a temperature of 278.3 K or 5.3°C where 1360 (Wm^{-2}) is the solar constant. Introducing an albedo of 0.30 will give a temperature of -18.5°C. Since the mean surface temperature of Earth is +15°C the difference between mean emission temperature and mean global surface temperature is calculated to be 33.5°C. Call this the mean atmospheric interface/surface temperature difference (AISTD). This is for incomprehensible reasons called the "greenhouse effect" and is claimed to be caused by special gases, preferentially carbon dioxide and methane. In II:7 it is shown that the mere existence of an gaseous atmosphere that to a minor degree is transparent to Sun light is bound to show a "greenhouse effect" with or without greenhouse gases. If correct, the greenhouse effect is merely an important climate variable in the minds of some

scientists.

Large land and sea areas were ice covered during LGM. Let us assume that the albedos for ice, snow and oceans are 0.8, 0.3 and 0.05. A rough estimate of AISTD during LGM, assuming 1/3 Earth is covered by clouds will yield a value of 38.1°C, indicating a Holocene-LGM temperature difference of 4.6°C.

If this value by chance would be correct, the true mean temperature difference along the equator has to be less and the mean difference in high latitudes have to be greater for reasons not included in this crude model.

1.4. Varying infrared emission into space

Obviously the overwhelming amount of thermal energy in the climate system originates from the sun. Still, for several reasons, it is hard to believe that this is the whole story. One is the ever increasing evidence of solar-terrestrial relationships coupled to climate variables. These directly inform us about a general lack of understanding of the climate system. An intriguing aspect on climate is tied to the cause of sunspots. A large one, covering an area comparable to Earth's surface, seems to be black because its temperature is about 1,500°C lower than the surrounding atmosphere of the sun. The light intensity from a sunspot has decreased by 70% or from about 65 million to 20 million Wm^{-2} . This is an example of temporal variations of energy emission from a celestial body which is caused by physical processes not understood by science today. It might also be an example of "climate change" on the Sun, if sunspots are created by processes originating outside the Sun.

Solar energy absorbed by the atmosphere and hydrosphere has to leave Earth via long wave infrared effect emission. As have been pointed out in II:7, the process of turning sensible or latent heat stored in the atmosphere into quanta that leave Earth, is the limiting factor in the energy transfer of effect into space. "Warm" air, must to a large extent, enter the level where the final emission into space can occur. But is the atmosphere of Earth a true "black body" emitter? The answer is definitely no, but in what ways?

We have to stay openminded about unknown factors, originating from within or outside the atmospheric/hydrospheric systems, that can affect the infrared radiation from Earth. *Space is the final sink for energy entering this system.* A hypothetical solar-terrestrial or planetary influence on the infrared emissivity from the atmosphere would certainly be able to explain many observational and climatological evidence. If such influences exist it would definitely affect the surface winds on Earth, especially if its main impact is directed toward polar regions.

2. Interhemispheric energy transfer

2.1. The age of energy

The "age" of energy might be a useful concept for understanding the dynamics of the dominant circulation systems in the atmosphere and the oceans. Two main categories of energy can be suitable to define, "positive" energy produced by solar insolation and "negative" energy produced by heat sinks.

The mean age of positive energy are closely coupled to where sensible heat is created. We can separate four important types of positive energy mostly depending on its storage in the terrestrial climate system. The first one is light

quanta that directly goes back into space after one or more reflections which is measured by the albedo. This type directly leaves the terrestrial system and its importance is tied to the total amount of light quanta that is turned into heat in the system.

The second type is directly or almost directly transferred to sensible heat in the atmosphere by direct absorption of light quanta or indirectly by the heating of land surfaces. Very little of this energy is transported to water bound energy by warm surface winds. Infrared quanta can only penetrate a water surface some millimeters and this process is neglectable. Most of the positive energy in the atmosphere is doomed to escape back into space within days, since the atmosphere loses sensible heat at a rate around 1°C per 24 hours.

Much of the solar energy is captured by oceans, seas and lakes. All the oceans would be covered by an ice sheet within five years if the Sun stopped shining. Oceans usually store heat over seasons. It will require all the global average nonreflected insolation during half a year to heat the upper 200 m of the ocean surface layer 3°C . Thus we can estimate the mean age of waterbound sensible heat in the ocean surface layer to be up to 5 years. Sensible heat, below the ocean surface layer can probably reach ages of hundreds to thousands years.

The fourth type of positive energy is the one that is turned into organic matter. Since most of it decays within weeks to 10 years a proper "effective" age could be a couple of years. The decay of organic matter always occurs but the seasonal variation is smoothed. It actually supplies energy during winter time which can be directly measured by the seasonal variation of carbon dioxide in NH .

Negative energy usually has a longer average length of life than the positive ones. This mainly depends on the sinking of cold air and water until reaching the ground or the bottoms of oceans where there might exist mountain ranges or ridges holding the cold stably stratified fluid in place for long times. In the atmosphere the largest sinks are situated in polar or subpolar areas and the results are often immense cold air masses called mobile polar highs (MPH, II:3) that sooner or later start moving towards the equator. The life time of these air masses is in the range of a week to a month. Their importance for life on land is pronounced since they will always affect land surface temperatures directly. Negative energy in the air is often transferred to negative energy in oceans or lakes by the freezing of water to ice or snow.

The atmosphere is the major sink for positive ocean energy. The processes that can create large amounts of ocean bound negative energy exist in subpolar or polar areas. Effect transfer caused by contact between polar sea ice and surface ocean water is a process that quantitatively depends on surface water speed. Another effective process is the contact between MPH:s and medium warm surface ocean water. At high wind velocities an effect transfer of 400 Wm^{-2} has been measured. This is a loss rate exceeding mean incoming solar insolation at the ground level in the middle of Sahara during summer.

A process, easy to observe, is the one associated with freezing of sea ice. It is important for producing very cold, high salinity ocean water. The process requires a relatively thin cold sea ice or a mixture of broken sea ice and open sea water and is thus limited to polar and subpolar waters in the first place.

The age of negative ocean energy can be high since the cold water sinks to

the deepest levels in the ocean. If new cold water production ceases, the coldest water will just stay at the deepest part of the ocean until slow mixing processes eventually will increase the temperature. The age of negative ocean energy will thus depend on the degree of cooling and circulation of deep waters. It can easily reach ages of 1-5 ky. Much higher ages can be achieved by negative energy stored in glaciers.

2.2. The balance of energy

The mean age of energy has been emphasized since there are severe restrictions to mix certain types of energy with each other or to transfer a specific type to another type. Combining the aspect of energy age with the influence of land and ocean distribution (Table 1) will result in quite remarkable deductions. Let us perform an exercise to exemplify this.

Assuming the Earth axis to be perpendicular to the orbit of Earth, we can calculate incoming effect to the atmosphere and the oceans as a function of hemisphere and time period (Holocene and LGM). The following assumptions will be made:

- 680 W m⁻² will reach Earth's projection as seen from the Sun.
- 95% of incoming effect to the ocean surfaces will be absorbed (cloudless sky).
- 70% of incoming effect on land will heat the air (cloudless sky).
- 1/3 of all areas will at any time be covered by clouds with an albedo of 80%.
- 30% of the insolation on land areas will be absorbed by plants and trees.

With this crude model the calculated insolation NH surplus over SH, on land, on oceans and on ice are shown in Table 2.

Table 2. Northern hemisphere effect surplus.

Effect	land		ocean		snow
	%	x10 ¹⁵ W	%	x10 ¹⁵ W	%
Holocene	10.1	4.3	-8.1	-4.7	-2.0
LGM	5.4	2.3	-7.9	-4.6	2.5
Difference	4.7	2.0	-0.2	-0.1	-4.5

Although both hemispheres receive exactly the same amount of effect the hemispheric effect asymmetry is created by the uneven distribution of land, ocean and snow/ice surfaces. This asymmetry remains to a large extent during LGM. Since atmospheric bound energy will be lost easy to space and much is lost locally and by atmosphere-ocean interaction, the values in Table 2 could be interpreted in the following way:

1. The SH will lose more effect than NH due to large snow covered areas during Holocene. This situation will be reversed during LGM when NH reflects

more solar effect than SH.

2. The NH Holocene atmospheric sensible heat surplus is reduced to half the value during LGM.

3. NH atmospheric sensible heat will to large extent be lost within NH.

4. SH sensible heat excess in the oceans stay about the same value during both Holocene and LGM. This sensible heat will constitute the major energy imbalance between the hemispheres. *There has to be a transfer of effect between the hemispheres and it has to occur during both Holocene and LGM.*

To equalize the energy imbalance in oceanic sensible heat, about 2.3×10^{15} W has to be transported across the equator if no energy loss to the atmosphere is taken into account. For reasons not treated here most of this effect is transferred by The South Equatorial Current (SEC) and by the Gulf Stream. Assuming that the water entering the Northern hemisphere is $+24^\circ\text{C}$ and the temperature of the returning deep water is $+3^\circ\text{C}$, the water flow needed to supply NH with the required effect will be $26 \times 10^6 \text{ m}^3\text{s}^{-1}$ or 26 Sverdrup. According to McDonald (1996) the flow rate is 30 Sverdrup across the equator in northward direction and 27 Sverdrup in the other direction. The estimate here might be fortuitous for several reasons but it is probably in the right range.

The relatively long life time of water bound sensible heat will make the flow continue regardless of season although modulated by it. Such a situation does not exist for sensible heat in the atmosphere. Most of this effect has to be transferred in a week or it will be lost to space. Still, atmospheric bound inter-hemispheric effect transfer constitute a great secret in climatology. Nature has provided a method to overcome this shortcoming when SH atmospheric effect is relocated to NH (II:5).

2.3. General aspects on modulation of interhemispheric energy flows

Now we are able to reach some qualitative deductions regarding the inter-hemispheric energy flows. The main variables we will consider important are at this point:

- Geographical distribution of land, ocean and snow/ice covered surfaces
- Different types of energy and their mean life time
- Energy sources and sinks in atmosphere and hydrosphere
- Variation of insolation depending on celestial parameters

A constant value of insolation will thus create an imbalance between the both hemispheres relating to stored energy. The imbalance primarily depends on (1) larger ocean areas in SH, (2) that the oceans absorb a large amount of insolation reaching its surface, (3) that sensible heat absorbed by or transferred to the atmosphere (dominantly in NH) will soon lose its energy into space. This imbalance will primarily be counteracted by advection of warm surface water from SH to NH across the equator and the return of cold bottom (intermediate) water in the opposite way.

In a Holocene situation, the following atmospheric situation is probable. The surplus of positive energy transferred from landmasses in NH will advect in a northerly direction, to a large extent escape into space and during summer partly be exported to SH via the monsoon system. The corresponding process in SH is very special with large effect transfer during austral summer to NH

(II:5). The production of negative atmospheric energy will occur from a larger area in SH than in NH. The produced MPH:s from Antarctica will effectively be disintegrated to a large extent by contact with the circumpolar surface waters, where surface wind speeds are high as is the effect release from the ocean surface layer.

The higher NH effect loss directly into space and the topography of northern NH will make the MPH:s produced in NH cooler than in SH. They will to a large extent move over land areas before they reach the ocean and the equator meaning less energy transfer from ocean water. More surface air will thus move from north to south over the equator than in the opposite direction. This has to be compensated by advection of air masses moving from south to north at a higher level across the equator. Thus, the positive surplus energy in SH will be transferred to NH primarily by ocean surface currents and to a lesser extent by upper tropospheric air masses that replace northerly cold MPH:s (II:5).

The scenario above is modified by two major topographic features. One is the existence of the Greenland, Island and Norwegian seas as tremendous high latitude energy sinks for positive ocean energy. The created cold bottom water coupled with the need for the SH to get rid of its positive ocean sensitive heat supply actually decide the path for warm surface water, incorporating the action of the coriolis force. The warm ocean water has its origin in the Pacific and Indian Ocean and moves around South Africa to its final surface position in the northernmost Atlantic Ocean.

The second important orographic feature is the Tibetan Plateau which is outstanding because of its height and size. The fact that it is situated at mid-latitude and receives considerable solar effect, promotes its climatological importance. It will act like a chimney in summer time by producing air with an exceptional high potential energy that will flow across the equator thus transferring some of the NH atmospheric positive energy to SH. It should be noticed that the monsoon system is here claimed to overcome the forces producing the ITCZ (II:3-5).

2.4. Temporal variations of interhemispheric energy flows

Leaving the assumption of Earth's axis being perpendicular to its orbital plane, the Milankovitch variables will dominate solar insolation variations.

Variations in tilt, eccentricity and precession will interact with the above mentioned energy situation in both atmospheres. The imbalance of energy storage in the hemispheres means that Earth's climate will respond to changes in eccentricity despite that such changes do not cause a substantial hemispheric change in integrated effect during a year.

3. Horizontal density forcing

3.1. Basic concepts

We are all very familiar with the effect of the gravity force, causing an oil to float on top of water or water to sink through a bucket filled by oil. Denser gases and liquids sink in lighter ones. The equilibrium situation is set by the form of the container. If we rotate the bucket at a constant angular velocity (a cylindrical shaped one) around its axis of symmetry the oil floating on top of the

water will find a new equilibrium with a depressed oil level in the centre of the bucket and with another height of oil along the radius of the bucket.

In a way, the water on Earth is spilled out into a "container" formed by the solid Earth and on top of the water, the air is resting. The rotation of Earth makes the atmospheric mass surface density to differ at the pole and the equator.

At equilibrium 10,357 and 10,302 kg air will rest on each square meter at the equator and the pole at sea level if the sea level pressure is 101300 Pa at both places. The water in the oceans is arranged in a similar way. The difference in mass surface density balances the horizontal acceleration caused by the rotation of Earth in the first place. This acceleration is always directed towards the equator and has a maximum at 45° latitude and is zero at the poles and the equator. The centrifugal force thus decides the deviation from a spherical form of Earth, the hydrosphere and the atmosphere. The condition of mass balance is the prime requirement to avoid motion of mass in the atmosphere and oceans but there are two more restrictions to be met before the winds stop blowing.

The atmosphere and the oceans have to be stratified in a stable way, meaning that the densities in the fluids have to be monotonically increasing upwards which is obvious since the heavier parts otherwise would sink and cause motion.

The third condition to be met to avoid motion is that the atmosphere and oceans at a constant gravity potential should have the same density. Then there will be no motion caused by the horizontal component of the centrifugal force. Consider an example. If the density of the atmosphere at a specific gravity potential level differs at a certain latitude there will be a resulting equatorward acceleration of the heavier part alternatively a resulting poleward acceleration of the lighter part. The third condition can hardly be met in the real world at least not as long as there are any energy flows entering and leaving an atmosphere or an ocean. This means that circulation systems have to occur in the atmosphere of a rotation planet (or sun) and that the intensity of the circulation will be proportional to the angular velocity of the rotating planet (or sun).

The horizontal pressure difference can be expressed by:

$$dP = D_d a_h dL \quad (2)$$

where D_d is the difference in density between two air parcels at a specific potential surface, a_h is the horizontal component of the centrifugal force and dL is the latitudinal length of the denser part of the atmosphere or ocean. dP will here be called horizontal density pressure which causes horizontal density forcing (HDF). dP can be integrated from the pole to the equator along all constant gravity potential surfaces. If $dP=0$ at all arbitrary paths of integration, meaning $D_d=0$, there will be no motion in the atmosphere or oceans.

The larger dP that exists in a situation, the stronger circulation can be expected to develop. The most intense action can be expected around mid-latitudes since a_h has a maximum at 45°.

3.2. The production of maximum density differences

If an enhanced intensity in atmospheric and ocean circulation contributes to the increase of infrared emission from Earth, which has been suggested earlier, then there are reasons to examine what factors cause the production of maximum density differences in air and in ocean waters. In the atmosphere, the following factors are of importance:

- High emission of infrared radiation from land or ice surfaces
- A minimum of solar insolation
- Dry air
- A production site at a low elevation

If these conditions are met, a cold air mass will be developed over land with a temperature inversion above it. The favorite place for the production in the grand scale should be arctic or subarctic areas during winter time. This is exactly where and how the most massive MPH:s develop. The MPH:s formed in the Antarctic region are smaller for topographic reasons. The Antarctic ice cap promotes adiabatic wind systems that will flow over the ocean before the air masses can become extremely massive or cold. The dynamics of MPH:s has been excellently described by Leroux (1993).

In the small scale large density differences will be produced in deserts during nights. This has created a circulation named "low level jets" in northern Australia during austral winter, as a phenomenon that remains a scientific puzzle (Clarke, 1979).

The oceans are covered by a warm lid of water since the solar energy cannot penetrate surface water more than a few hundred meters. Production of strong density differences in ocean waters are favoured in polar or subpolar regions by the transfer of waterbound sensible heat to the atmosphere. A strong density difference in water is favoured by the following factors:

- A minimum of solar insolation
- A high salinity
- Ocean surface contact with MPH:s during windy conditions
- Ocean surface contact with a relatively thin, cold ice sheet under the influence of surface currents.
- A basin which can be filled with cold water before HDF makes it move equatorward.

Also here the topography in NH is favourable. The imprints of cold heavy bottom water can be traced in the GIN sea and the northernmost Atlantic. Bottom currents have built up enormous sediment ridges since 35 million years with the largest deposition rates 5-2 million years (Wold, 1994).

The cooling processes of both the atmosphere and the oceans are stressed regarding the production of maximum temperature differences. In the atmosphere, a high solar intensity will help in producing an adiabatic lapse rate (II:8) which will level out density differences. Strong solar insolation into the ocean will produce a cover of warm water at the ocean surface. As long as that cover is homogenous at a certain latitude it will not contribute very much to horizontal density forcing. Even here the cooling of bottom and intermediate waters will develop more density differences than the heating of surface waters. These arguments explain why *the cooling processes are more important than the solar insolation variation in producing strong HDF* and thus causing strong circulation systems on Earth of importance for climate change.

3.3. The implication of HDF

In the grand scale HDF is the prime causative agents for atmosphere and ocean circulation. In the atmosphere, the MPH:s produced in both hemispheres move equatorwards where they desintegrate because of warming. These cold surface air masses are replaced by lower latitude tropospheric air. When moving polewards such an air mass try to keep its momentum and speeds up creating the westward moving jet streams under the influence of the coriolis force. They are most developed during the winter in both hemispheres. The better production conditions of cold surface air masses in NH promote a quantitatively stronger jet wind system than in SH.

The amplitude of angular momentum of northern winter jets are about double that of the southern ones during the austral winter. There is an excellent correlation between the *total* of Earthly jet wind angular momentum and the variation of the length of the day regarding periods from a week to years. Strong jets on Earth are correlated with a slow down of its rotation rate (Barnes et al., 1983) It is seasonal redistribution of atmospheric mass surface density that is causing the slow down, especially noticable during the boreal winter. It works exactly the same way as the speeding up of Earth's rotation during glacial times because of ice accumulation in polar areas.

HDF is an important if not the main driving force for the Hadley circulation (II:4). HDF is equally important in creating ocean currents. The circumpolar current is created when cold bottom water is replaced by shallower water originating from areas closer to the equator. Its large momentum speed up the westward motion under the influence of the coriolis force. In a smaller scale water at a depth around 500 m gets deflected towards the west and hit the west coasts of the continents creating the well known upwelling phenomenon.

The consequences of HDF are vast. This force is prior to and create the pressure differences which control geostrophic winds and currents. In fact, both the circumpolar jets in the atmosphere and the circumpolar current can be considered as global geostrophic flows. Here it will be strongly emphasized that the circumpolar current is *not* driven by the wind system to any substantial degree.

The most dominant flows in the atmosphere and the oceans are proposed to be created because of density differences mainly caused by variations in infrared emission into space in combination with the horizontal component of the centrifugal force. Since there are small restrictions for HDF to work in almost any atmosphere, its effect can be observed on almost any rotating planet with an atmosphere. Jupiter shows an example of a violent and spectacular atmospheric circulation system, which is no surprise since it has the fastest rate of rotation in the solar system causing a day and night to be less than nine hours.

4. The Hadley circulation

The atmosphere of Earth is constantly in motion. The simple fact that matter cannot disappear actually means that all substantially large displacements of fluids have to be involved in circulating systems. As long as large quantities of these fluids cannot pile up, the moving fluid has to be replaced. One such circulation of air is named the Hadley circulation. It is defined by the raising air

along the intertropical convergence zone (ITCZ) and its motion in polar directions. The air descends along the high pressure zones around 30° latitude and moves back to the equatorial region as trade winds. The ITCZ is situated close to the equator but its mean position follows the zenith of the sun although its position over land areas is less pronounced. The Hadley circulation is more intense during the winter season in both hemispheres.

Mostly the Hadley circulation is considered to be driven almost exclusively by solar energy through the heating of the land and sea surfaces in the equatorial zone. Here it is argued that solar insolation is not that dominating, as is generally thought, in creating the Hadley circulation. The main arguments follow below.

A quick look at a global atmospheric pressure map will show that the most well developed high pressure areas around 30° latitude are situated over oceans. The most stable position of ITCZ is over oceans. The strongest developed circulation takes place during the winter seasons. A significant part of the solar insolation on land will heat the air directly. Of the insolation reaching the sea surface about 95% will warm the water or be used for biological purposes and 5% will go back into space. The oceans can only indirectly heat the atmosphere with an inbuilt time delay and a dependence on both atmospheric surface and ocean surface motion. The ITCZ is geographically restricted to a narrow zone, less than 100 km, where it is well developed. The temperature of the ocean surfaces is generally warmer in the western areas and colder in the eastern ones where the high pressure areas are more pronounced.

Information in II:3 promotes the opinion that the Hadley circulation primarily is a result of trade winds hitting each other, transferring horizontal kinetic energy to vertical kinetic energy. A secondary phenomenon is that the trade winds have had time to accumulate a substantial amount of water vapour producing low density air which is relatively easy to lift. The upward motion will also be sustained and driven by heat release, when water vapor condenses and some of its energy is heating the local air column, and thus enforcing the upward air motion.

Two more arguments will be mentioned. During wintertime a cold MPH might reach the equatorial regions and cover an area equal to half South America with a lid of "cold" air 1-2 km in thickness producing a very stable density stratification during several days. At such a situation the ITCZ might develop on top of the cold air lid. Thus, the ITCZ is able to develop without any local surface supply of energy. The second argument is that latitudinally banded atmospheric motion exists on all the big planets where solar insolation is down to 0,1 % of what Earth is receiving. Still there exist forces keeping this atmospheric motion active forever in our time perspective.

The reasoning above is important for climatology. If the Hadley cell circulation is not primarily driven by solar energy variations new possibilities to understand climate change might evolve. Especially the structure of the Hadley circulation might change much more between glacial and interglacial conditions than is generally assumed (Fairbridge, 1972).

5. Subsidence energy

Sensible heat, bound to the troposphere and stratosphere, is able to move downward to add energy to the atmospheric or ocean surface layer in certain

situations. When this happens the energy added to the atmospheric surface layer is here defined as subsidence energy. Since this motion pattern mostly co-vary with high pressure situations it is easy to understand that subsidence effect transfer often is coupled to sunny weather, at least over land areas. Different types of subsidence energy can be described relating to their spatial and temporal extension. The subsidence energy is transferred to the high pressure zone from above and can directly be spotted as an inversion layer in common meteorological temperature charts. The downward advection of effect in this situations has often been omitted or substantially underestimated in meteorological and climate models. Especially the transfer of effect from SH to NH during winter is not recognized in climate models. The development of high pressure zones might be triggered by tidal effects. This is a potential cause for many published correlations between climate variables and sunspot data.

5.1. Low latitude type

This type is fairly stationary and best developed around latitude 30° north and south in winter times, both over land and ocean areas. The high pressure zone constitute a part of the Hadley circulation. The relative quantity of subsidence effect relating to solar insolation is greater during winter than summer. The formation of the high pressure zone is so stable that it survives despite fairly strong solar insolation although it weakens considerably during summer time.

Over land areas, the surface air cools during nights and is heated during mornings and early daytime. Around noon heated air parcels are moving up, smashing the inversion layer where the lowest part (500-1000 m) breaks down and within hours transfer effect straight down to the surface. This occurs along a truly adiabatic temperature profile (II:8), between the newly formed, higher up developed inversion layer and the surface. The subsidence effect can easily reach 50% of the surface effect transferred by direct solar insolation in a clear sky (unpublished data from northern Australia, Koorin expedition 1974). During night time the inversion layer is slowly moving downwards again.

Over ocean areas the daily pulses of subsidence effect input to the atmospheric surface layer is smoothed since the ocean absorb most solar energy. The upwelling zones west of Africa and South America are typical subsidence areas. The formation of the high pressure zones are strengthened by the cool upwelling water which actually is warmed by subsidence effect. This is an example of unusual transfer of sensible heat from the atmosphere to sensible heat in the oceans. The center of the subsidence area is marked by the minimum level of the inversion layer which can be quite low (less than 500 m). The decreasing height of the inversion layer towards the high pressure center can be followed both latitudinally and longitudinally over long distances.

5.2. Non-permanent high pressure zones

Atmospheric high pressure centra can develop and become semistationary for unknown reasons. There is a tendency for high pressure zones to develop along 0-20°E and 160-180°W at midlatitude in NH. These situations can last for a month and are called "blocking situations" since a high pressure area is developed at a rather high northern latitude and is blocking the common westerly winds. The "blocking situations" over Scandinavia usually occur in

spring or early summer time. Statistics about these events have been published (Lejenäs, 1983; Lejenäs & Ökland., 1983). The blocking situations imply that an increased effect will reach the atmospheric surface layer via subsidence which is added on top of the increased solar insolation effect accompanying the less cloudy high pressure situation. May is the sunniest month of the year in the Stockholm area because of blocking situations.

Many articles have dealt with the cyclicity of drought periods on the north American continent. Some of these show sunspot influenced periods of 11 and 22 years and also a cyclicity of 18.6 years. The latter one might be related to the occurrences of solar and lunar eclipses. It is here suggested that these relationships are caused by periodic creations of atmospheric high pressure zones which sponsor dry conditions caused by the extra subsidence effect.

5.3. Interhemispheric subsidence effect transfer

Important interhemispheric effect transfer occurs via MPH:s, the monsoon circulation and large scale motion of air masses from SH midlatitudes to NH midlatitudes. The MPH:s do not directly involve subsidence effect. Still they are involved in the hemispherical mass balances because MPH:s more often move across the equator from north to south than vice versa. The effect transfer from NH to SH during boreal summer via warming of air on the Tibetan plateau is important. Much of this effect is probably delivered in the low latitude high pressure zones in SH. This type of subsidence effect transfer has been discussed above.

Northerly interhemispheric subsidence effect (NISE) constitute a key physical mechanism affecting the climate of Earth by transferring effect from SH to NH during boreal winter. This subsidence effect involve massiv transfer of energy levelling off the cold spell of NH winter. The energy source area is the windy atmosphere above the circumpolar current that gets warm during the austral summer. The maximum effect is transferred during february-march. It is next to the Gulf Stream the most important physical mechanism to balance the unequal amounts of energy stored in SH and NH described in II:2.

Fig. 1 (Levin, 1980, Nydal, 1983) shows the distribution of the ^{14}C isotope mainly produced by the hydrogen bombs which exploded 1963 in NH. The time series in Vermont 47°N , 10°E and in Wellington 41°S , 174°E have different characteristics. During the first 4 years after 1963 the Vermont series show a decreasing seasonal component on top of the exponentially declining signal. In Wellington there is a time delay and the seasonal variation is (almost) absent. The boreal winter decline of the Vermont signal is proposed to be produced by the overflow of SH air to NH. This means that the seasonal dip in the Vermont series should be approximately proportional to the difference between the ^{14}C isotope values in the two hemispheres during a transition period. When the values in both hemispheres approach each other the midwinter seasonal dip should disappear which is what is shown in Fig. 1.

Other observational data support this interpretation. Both carbon dioxide and methane mixing ratios have interhemispheric gradients with higher mixing ratios in the NH. Both gases show a boreal mid-winter dip in NH seasonal variations in mixing ratios. These are proposed to be caused by overflow of SH air that dilutes the NH mixing ratios for these gases, as was shown by the ^{14}C isotope variations.

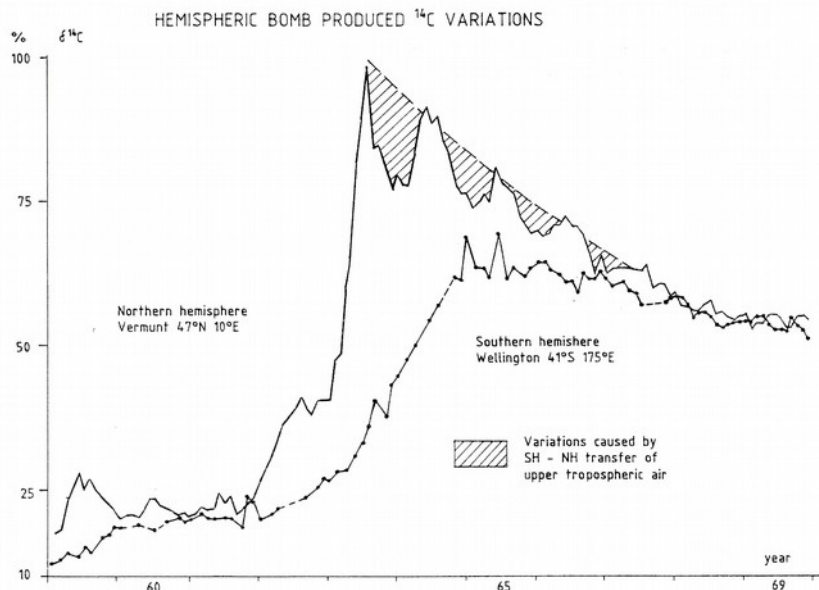


Fig. 1. The distribution of ^{14}C at Lat. 47°N (Vermont) and Lat. 41°S (Wellington).

6. Ocean and Atmospheric circulation

6.1. Main features

Seen from space, infrared emission is centered around a gas emission temperature of -18°C (II:1.3). Even if there are latitudinal differences around this value the gas emitting the effect into space have to be situated where the atmospheric temperature is close to this value. Assuming an adiabatic temperature lapse rate (II:8), the average gas emitting level would be around 3000-4000 m which would be about equal in both hemispheres.

If so, the energy imbalance produced by land, ocean and sea ice distribution on Earth both during glacials and interglacials (II:2), will necessarily lead to atmospheric and ocean circulations aimed to move energy to the coolest part of the middle and upper troposphere. A consequence will be a levelling of temperature differences in the atmosphere-space interface.

With these basic facts, the action of HDF, interhemispheric subsidence and the monsoon circulation in mind, we should be able to outline the main features in the circulation systems if we know where the major ocean heat sinks are located. The influences of tilt, obliquity and eccentricity will not be treated here.

6.2. Holocene conditions

The major climate feature, required to produce Holocene conditions, is NISE. A listing and characteristics of other important circulation systems could look like:

1. The production of MPH:s in NH (especially during winter) at a moderate rate creates the northern jet wind system.
2. Production of MPH:s in SH (especially during winter) creates the southern jet wind system. Maximum angular momentum in the northern jet winds are about double that of the maximum in the southern jets.
3. The excess of surface atmosphere mass transfer from NH to SH during boreal winter will help in creating the interhemispherical circulation that warm NH via the subsidence effect.
4. The MPH:s, solar insolation and HDF produce the Hadley circulation.
5. Interhemispheric ocean currents transport immense amounts of energy into NH mostly via the south equatorial current across the equator into the North Atlantic Ocean.
6. The major sink of ocean surface water energy in NH is the northern Atlantic and the GIN sea where cold water is produced which create bottom currents that move toward the equator and are deflected towards east by the coriolis force.
7. Some parts of the cold water is replaced by water that move northwards and is deflected toward the west and creates upwelling when hitting the African coast line.
8. The major sink of SH ocean bound sensible heat, is the ice/water interface around Antarctica. Cold water sinks and produces South Atlantic deep water.
9. Some of this cold water is replaced by water that moves north and is deflected towards the west by the coriolis force. This causes upwelling along the western coasts of South America and South Africa.
10. Some SH water, below the warm surface water, will move towards the equator and where it meets the same type of water from NH. Equatorial upwelling will occur, an equivalent to the Hadley circulation. This type of upwelling will be strongest in the equatorial Atlantic since the ocean temperature contrasts are largest in that ocean.
11. The summer monsoon circulation will help to reduce the NH excess energy during boreal summer by transferring energy to SH. The relative importance of the winter monsoon is much less.

6.3. Conditions during LGM

During glacial conditions NISE is intermittently cut off for unknown reasons. The direct consequence of a cut off would be that most effect transferred to NH have to rely on ocean currents and maybe marginally on the winter monsoon system.

The northern production of MPH:s would be intensified because of higher albedo over ice covered surfaces. These MPH:s would cool the ocean surface and not get deflected in an easterly direction which happens in the modern situation. The production of MPH:s will increase also in SH and the MPH:s will not reach open ocean water until 50°S, which contributes to its maintenance. Thus the jet wind systems in both hemispheres would be much intensified but the NH system would still be the strongest.

The intensity of the Hadley circulation would probably increase tremendously and the trade winds would cover a much larger latitudinal range, the main reason being stronger HDF.

Polar-equatorial temperature differences will increase putting more emphasis on intrahemispheric circulation systems for the adjustments of temperature differences. The closing of NISE implies that a more massive cooling of ocean water in NH can occur. The warm water pathway during Holocene seems to stay intact but might not have capacity to transfer as much effect as during Holocene or at least not to compensate for the shut down of NISE. SH seems to build up occasional supplies of warm water masses at intermediate depths. The cold water from NH and warm water from SH are exchanged but it seems to occur in pulses that can have periods between 1-5 ky. These pulses have been especially strong along the Atlantic equator between South America and Africa. They might also cause the well known Heinrich events.

6.4. Classification of surface ocean conditions

In the surface layer of the pelagic ocean a manifold of physical, chemical and biological processes occur. In many respects, it is an incomprehensible system that is only partly understood. Here some aspects, important for the interpretation of scientific data (especially ocean drill core time series) are to be addressed. The atmosphere-ocean interface will here be treated in terms of its dynamic situation, meaning the motion of surface water and surface winds. Let us define three basic dynamic conditions that can prevail as a mean condition over long periods (usually 0,1-10 ky but sometimes 10-100 years).

1. Calm condition. Neither the current speed nor the surface winds are strong (Fig. 2, left).
2. Surface winds are calm or moderate and the water mass belong to an ocean current or to an upwelling region (Fig. 2, middle).
3. Strong surface winds are prevailing (Fig. 2, right).

ATMOSPHERE - OCEAN INTERFACE
Example of gradients in surface layer

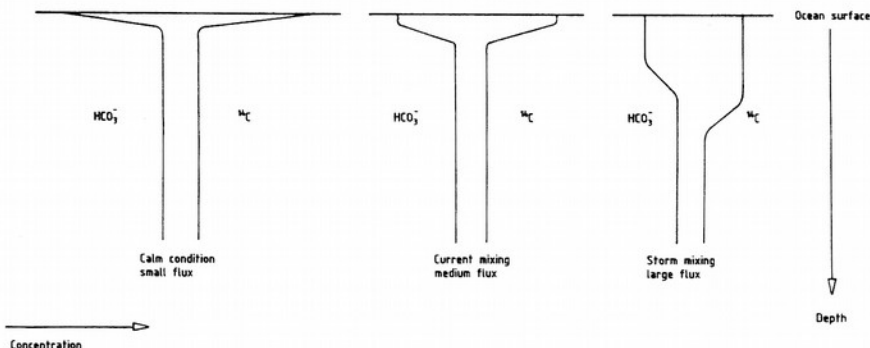


Fig. 2. The atmospheric-ocean interface as a function of circulation intensity.

The atmospheric-ocean interface as a function of circulation intensity is illustrated in Fig. 2. The classification above is based on the persuasion that the average dynamic situation of the ocean surface affects biological life, mixing processes between the atmospheric gases and the ocean water and the signature of organic debris sinking to the ocean bottom from the ocean surface layer. Many scientists have tried to relate inorganic carbon concentration, ^{14}C , ^{13}C and ^{18}O values in carbonate to equilibrium conditions (temperature dependent) in the oceans. The main problem is that the ocean surface layer never is identical with the average ocean water mass regarding these quantities. It is even hard to find a meaningful mean ocean value for many variables since they vary fairly much between oceans. The surface layer of an ocean is an *anomalous zone* which influence all life in this zone and the debris falling down from the same. The conditions in the zone is highly sensitive to *fluid motion* and the *residence time* of a specific water parcel in the zone.

7. Climate and atmospheric mass

This part of the thesis is formulated as a formal proof, stating that the surface temperature of a planet with a light transparent atmosphere have to increase monotonically with increased atmospheric mass.

7.1. Assumptions

The following assumptions were made:

1. The contribution of effect from the interior (Wm^{-2}) of the planet is neglectable compared with average not reflected solar energy per unit surface area.
2. All into space not reflected sun light is sooner or later transferred into infrared light quanta. The energy stored in the atmosphere, oceans and ground is assumed to stay relatively constant.
3. The emission of infrared quanta from the atmosphere over a specific area of a planet, will approximately follow the law of "black body" radiation and have a limited local deviation from the global mean "black body" temperature.
4. Adiabatic temperature laps rate will exist from the ground level at least along the equator during day time.
5. The mean free path for both sun light quanta and infrared quanta is assumed to be shorter with increasing density (number of molecules per volume) of the atmosphere. The mean free path for sun light quanta is assumed to be longer than the one for infrared quanta.
6. The mixing ratio of gases in the atmosphere will stay constant.

Comments to the assumptions:

Assumption (1) and (2) should be considered valid if the probability is high that they were true at a specific time during the past 100 million years. Temperature variations between glacials and interglacials are considered as variations around a longer term mean temperature and associated energy accumulations are considered as minor, despite their strong influence of Earth's life forms.

Condition (3) implies that the atmosphere of Earth, as seen from space,

have to emit the bulk of infrared quanta from an atmospheric gas at a mean temperature close to -18°C (ASI, II:1.3). If ASI would be warmer than -18°C during a long period, Earth would constantly loose energy into space which cannot happen according to (2). Neither can ASI be constantly cooler since that would cause a monotonic accumulation of energy in the climate system of Earth, which condition (2) forbids. Assumption (3) implies that sensible heat in the atmosphere, have time to move vast distances before reaching ASI and emitting infrared radiation into space. This part of the assumption is supported by observational evidence from Earth's and Venus atmospheres, via measurements from space of infrared emission.

Assumption (4) guarantee the existence of vertical motion starting from the surface of the planet and the creation of an adiabatic temperature laps rate, at least occasionally over large parts of the surface of the planet. If condition (4) is not met the situation could theoretically be similar to the one in the oceans on Earth. A warm surface layer might then develop with a cooler bottom layer underneath. Observational evidence from the atmospheres of Mars, Earth and Venus support the assumption. On Venus an adiabatic temperature laps rate exists although only some percent of the Venusian insolation reaches the surface of the planet. Assumption (4) is thus a requirement which is highly dependant on the light transparency in an atmosphere.

In a cloud free Earth atmosphere at least 50% of the light quanta will reach the surface of the planet. A small part of infrared quanta emitted from the surface of Earth will pass directly into space. Thus, the mean free path of light quanta are longer than the mean free path for infrared quanta in the atmosphere of Earth according to observational evidence. There are no reasons why this situation wouldn't be the same in atmospheres on other planets. On a theoretical basis, it seems plausible that the absorption of both light quanta and infrared quanta, increase monotonically with the number of molecules per unit volume, which is proportional to density. Condition (5) is thus supported by theoretical and observational evidence.

Assumption (6) is made to avoid the discussion of atmospheric composition. It is a secondary influence since the proof is valid for any constant atmospheric composition.

7.2. Statement

The surface temperature of the atmosphere will increase with increasing mass of the atmosphere.

7.3. Proof

According to (3) a major part of the infrared emission into space, is emitted from ASI. Condition (5) requires that the density of the atmosphere, where ASI is situated, has a maximum absolute value, since otherwise most part of the infrared radiation should be reabsorbed in the atmosphere and ASI would have to be situated higher up according to the definition given above. In that case the density in ASI would be still lower. The mean average emission temperature of ASI is given by condition (3). The mean temperature at the ground level has to be higher than the mean emission temperature in ASI according to (4). Given the density of ASI, the density of the atmosphere at sea (or mean ground) level,

the adiabatic temperature laps rate according to (4) and the ideal gas law, the surface temperature of the planet can be calculated. Since the density of ASI is relatively constant it is independant of the total atmospheric mass surface density (kgm^{-2}) of a planet. Thus, the surface temperature has to increase when atmospheric mass increase, which should be shown.

7.4. Comments

The density of the ASI might depend on the composition of the atmosphere, but given a specific constant composition, the surface temperature would increase if the atmospheric mass surface density increased.

Observational evidence can be strengtened by the use of analogies from other planets. Some are listed below. The condition (3) applies very well on Venus, Jupiter, fairly well on Earth and not well on Mars. The condition (1) applies very well on Mars, Venus and Earth but not well on Jupiter. Condition (2) and (5) applies well on all planets with atmospheres. The conditon (4) applies well on Mars and Earth and fairly well on Venus but not well at all on Jupiter.

8. Adiabatic laps rate

An adiabatic process in an ideal gas infers that if the gas changes temperature and thus also volume and density, it does that without exchanging energy with the surroundings. The rate of decrease in atmospheric temperature with respect to height is called the lapse rate. If the energy content per mass unit is constant in the atmosphere (the potential temperature is constant) then the lapse rate is adiabatic. The theoretical formula discribing temperature change as a function of height is written as:

$$dT/dz = g/c_p \quad (3)$$

where T is temperature, z is height, g is the gravitational acceleration and c_p is the specific heat capacity at constant pressure. Since both g (9.8 ms^{-2}) and c_p ($1004 \text{ Jkg}^{-1}\text{C}^{-1}$) are fairly constant, the (dry) adiabatic lapse rate in the atmosphere is around 10°C per km. Most of us have experienced that this formula is valid in real life. The atmospheric temperature outside an airplane is often around -60°C at an height of 8000 meters. The basic requirement to keep a laps rate adiabatic is a continous effect transfer to the surface of a planet. If not, the surface will cool and cause an inversion above the cool atmospheric surface layer. During day time raising air parcels will quickly build up an adiabatic laps rate in the atmosphere and during the afternoon adiabatic conditions usually have its maximum vertical extent.

The formation of an adiabatic laps rate is important for several reasons. An airparcel can move both up and down in the atmosphere without loosing or gaining energy. This makes it easy to transport airparcels and also energy bothways in a vertical direction. The fast daily exchange of air from the inversion layer to the ground level is thus bound to occur during day time when maximal adiabatic conditions prevail. Only then is the downward effect transfer via subsidence possible (II:5).

The lapse rate in the atmosphere will always stay *approximately* adiabatic which is shown by the mean tempeatures at a number of Arctic and Antarctic

research stations in Fig. 3. Observe that the average temperature on Greenland is about 13°C warmer than in Antarctica. This is an effect of NISE, operating in the Holocene mode.

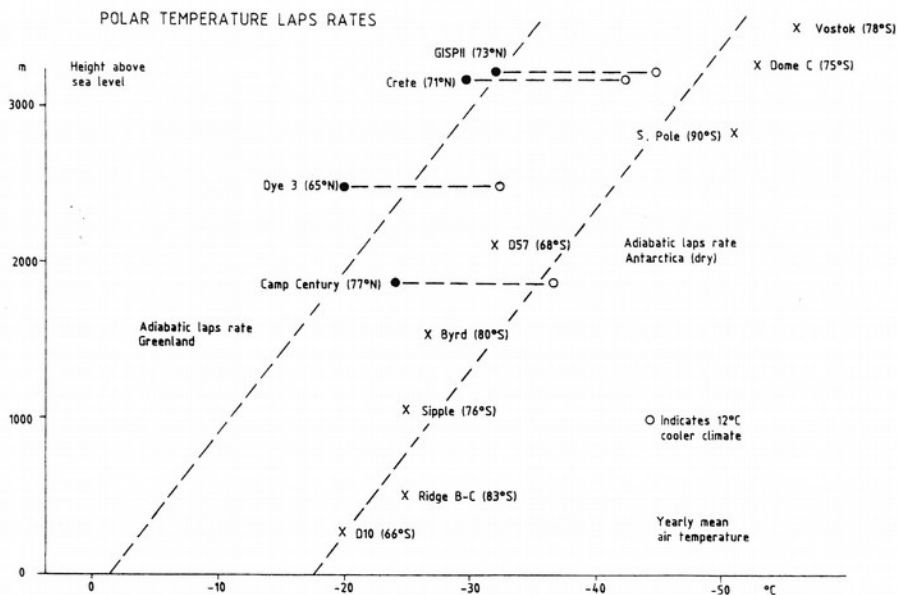


Fig. 3. Comparison of temperatures at Arctic and Antarctic research stations.

9. About diffusion and “eddy” mixing models

The concept of diffusion is originally tied to molecular diffusion and diffusion models have successfully been used to predict many micro physical processes. In many systems pure molecular diffusion is mixed with a flow of a gas or a liquid and then the mixing of molecules will depend on both laminar or turbulent flows coupled with the pure molecular diffusion.

In the atmosphere, lakes and oceans, mixing processes on different spatial and temporal scales constantly occur. To be able to treat such mixing processes in a simple mathematical way the “Mixing Length Theory” (MLT) has been developed. In this theory the concepts of eddy diffusion and mixing length (L) have been established. The latter replaces the well defined concept of “mean free paths” in molecular diffusion theory. In most climatological applications the pure molecular diffusion contributes to a neglectable part of the mixing process in the atmosphere and in the oceans.

The main idea in MLT is to describe the transfer of properties in a turbulent fluid. Effect transfer, exchange of trace gases etc, can be predicted by knowing the mixing length (L) and the mean velocity of the flow. This type of models have been applied to calculate wind velocity profiles above an ocean or above a forest covered land area, for example. It might work sometimes but the model

is far to crude or inadequate in many applications, one reason being that L normally is a function of both space and time and very hard to numerically stipulate in a relevant way in most cases. Models based on the MLT has been used extentionally to calculate physical properties in the planetary boundary layer

In this work mixing processes will be of a prime interest relating to carbon dioxide, ^{13}C , ^{18}O and methane exchange between the atmosphere and the ocean surface. Its is the opinion of the author that mixing processes in nature is hard to describe in a useful way with the help of MLT and the concept of "eddy mixing", an opinion that might be illustrated by Fig. 2.

10. Earth climate as an incomprehensible system

10.1. Types of incomprehensible systems

To cope with analysis of climate change on a rational basis we should consider different types of incomprehensible systems (IS). The first type is a system that exists today. We can call it a Modern Incomprehensible System (MIS) and by analogy we call a nonexistent system AIS where A stands for ancient.

When investigating IS it is favourable if the input signals can be applied and output signals observed on command. Such a system is called a Commandable Incomprehensible System (CIS). An IS where the input signals can not be sent on command will finally be called a Solid Incomprehensible System (SIS).

It is easily understood, that the climate system of Earth is of type AIS and SIS. The weather prediction people are dealing with a system of type MIS and SIS. Our doctors, treating human beings, handle an IS of type MIS and CIS. To gain information from IS, the basic idea is to send signals into the system and observe the output signals from it. Varying the inputs signals will cause varying output signals. By sending sine wave inputs of different frequencies, pulses, step functions etc, and observing the output signals, a lot of information regarding the IS can often be extracted without looking at the pieces inside the system.

The information gained in this manner, can sometimes be used to predict the future output of the system and can also lead to a better understanding of the construction of the system or subsystems. Other types of knowledge of system and subsystem funtions can also be added to enhance the detailed knowledge. The rate of gaining information from an IS, thus depend on the amount of input signals that can be sent into the system and the amount of output signals that can be observed. This fact means that some types of IS are easier to analyse than others. The order will be CIS+MIS, SIS+MIS, SIS+AIS. A system of type CIS+ AIS does not exist for obvious reasons. The IS type which is hardest to gain knowledge about is of the SIS+AIS type, that is an incomprehensible system which does not exist today and which cannot be commanded to react on inputs signals chosen by humans. The climate system of Earth is to a large extent such a system.

The strategy to examine any type of IS is basically the same; i.e. observing as many output signals as possible from the system and relating them to the input signals. But this can only be accomplished in one way regarding the climate of Earth. Nature itself is supplying the input signals to the system and also provides the output signals. This is done at a rate which cannot be

controlled. The only way to gather knowledge about climate change (as long as many of the physical, biological, chemical, geological etc, processes are not understood) is to collect data of input signals and output signals from the system or subsystems. These data have to concern old or ancient input and output variables by necessity, since a single cyclic period might be a million years or more.

Such data cannot be observed and measured in real time. They have to be figured out by records in glaciers, oceans and sediments. The desired quantity can very seldom be measured directly. Some other variables are measured and a formula is applied to transfer the measured variable to the desired one. The former one is called a "proxy" variable. This step is unavoidable when gaining knowledge of a IS like Earth's climate system, but it also include great risks in misinterpreting data.

10.2. Risks involved when interpreting data from IS

In nature most systems are a combination of fairly well known subsystems and incomprehensible subsystems. By extending subsystem knowledge, the system function can be partially identified; still, the system will continue to be incomprehensible. Still the type of risks, concerning interpretation of data from an IS, is the same whether one or all of the subsystems are of an IS type. For this reason a system will here be treated as an IS as long as one subsystem is of that type.

A CIS system has often been labeled a "Black Box" system meaning that the inside of the system is invisible. In this case the inputs and outputs are often well known. When getting output signals from an IS system some technical factors will make it easier to untangle what is inside the box.

The processes in the system should be time invariant. This is equivalent to claiming that the type of machinery (statistics) in a factory must not be changed during the time of observation. A car factory should not start making agriculture products. A human being can be considered to be run by fairly time invariant processes when healthy.

1. A long period of observations of input and output variables strengthen the possibility of interpreting data.
2. Sampling of input and output data at equidistant time intervals strengthen the possibilities for powerful signal processing.
3. Sampling at short time intervals favours the potential identification of unknown subsystems and the interpretation of transient responses in the output signal.

Unfortunately, there also exist some drawbacks in extracting knowledge from an IS.

4. The existence of all relevant variables (both input and output) have to be certified.
5. The input (independent) and output (dependent) variables have to be properly identified and separated from each other.
6. The causal restriction in the time domain has to be met. An input signal has to occur before the response in the output signal can be noticed.
7. Too few samples will lead to insecure estimates of frequencies, amplitudes etc.
8. It is almost impossible to prove that the processes in an IS are time

invariant.

Meeting the technical requirement above except the last one, does not guarantee a good result. A tremendous amount of information (from system signals) can lead to a false picture of the system or subsystem functions, if the requirements are badly fulfilled.

Regarding CIS the requirements can be better met by adding experimental results. The proposed requirements are hard to meet for SIS+MIS type, and the difficulties are most accentuated in SIS+AIS, to which we now know that processes causing climate change often belong.

10.3. Ancient climate systems

Knowledge of all climate processes with periods in the time domain in excess of 100 years have to be based on indirect measurements of climatic variables. This statement is valid even if instrumental records for some variables in a few places might extend to 300 BP. Sources might be pollen records, wood samples, peat deposits, loess deposits, lake deposits, ice core records, deep sea cores etc.

The information, extracted from nature, is often arranged in a way so that samples are gathered in a chronological order. This constitute a time series which often can be extended by overlapping time series of the same type but from a different location. The amount of samples and the sampling period are important for revealing variations within a broad frequency span. Of equal importance is the extraction of multiple variables from the same sample. In this way correlations between different variables can be established and sometimes unidentified subsystems can be detected and understood on a rational basis.

Still, the critical difference between establishing information from a CIS and a SIS+AIS is associated with the unavoidable indirect methods that have to be used to extract any information at all about the ancient system. To reach estimates of climate variables like temperature, albedo, ocean current flows, atmospheric circulation, other variables than temperature, wind speed etc, have to be measured. One essential problem involved in this "probing" to reach an estimate of relevant variables are the complexity of the "probe". In fact, the probe itself, often constitute an IS, thus adding to the risks involved in interpreting data. In such a case we have to face and overcome the risks involved in trying to understand an IS using another IS as a probe.

The risk using an IS as a probe can often be diminished by the fact that the probe system might be of type MIS. Temperature might for example be decided from pollen or plankton assemblages that are not extinct. In such cases the insecurity arising from using an IS as a probe can be diminished by examining the probe function in laboratory experiments or by field observations of living trees and of planktons. The worst case related to gaining information of climate change is to use a probe of type SIS+AIS.

10.4. Detector types

By now it should be clear that the decoding of the secrets of AIS:s is a tedious work but unavoidable if an increased understanding should be reached. The climate system is very complex and the way to a solution has to include the understanding of subsystem after subsystem hoping that some time the basic

system function can be explained by cause and effect relationships. When and if this stage is reached modelling might be of a good help.

Until then the work can be made easier by finding especially attractive locations suitable for sampling and by choosing detectors which minimize irrelevant influences on proxy data. Not all detectors have to involve IS and this fact makes it possible to order the type of probes regarding risks related to unknown influences.

The preferred order of detector system types are CS, CIS, SIS+MIS and AIS. The processes in a detector can be of a pure physical or chemical character or combinations of both. A detector of a biological origin is often influenced by physical and/or chemical processes. Almost all biological detector systems can be considered to be of an IS type and in the best case of CIS type. With this in mind it is possible to classify the type of probe in order to avoid proxy variables from the most controversial types of probes.

PART III

Analysis

1. Formulation of the climate change problem

There are unexplained changes in climate with periods varying from weeks to 100:ds of miljon years. For a period covering 200 million years there were no Ice Ages on Earth comparable to the ones during the last million years. Further more, the climate variables do not respond directly to variation in solar insolation input, a fact which is hard to explain. The physical causes for glacials to start and end are not identified. Especially intriguing is the symmetric response of global climate between the hemispheres, although they should theoretically be mainly unsymmetric if forced by solar insolation variations.

Short term, nonseasonal variations like the QBO and El Niño should be considered part of climate change. As long as they exist without specifying a persuasive cause and effect, it should be hard to claim that causes to other climate variations are fully understood. Finally, there also exists a multitude of unexplained solar-terrestrial relationships. These mostly concern temperature, precipitation and drought periods that are coupled to sunspot or solar wind variations.

There are numerous scientific articles written about all the phenomena mentioned above. They all belong to the pool of scientific research. With this in mind the climate change problem will be formulated as follows:

Can all types of observed climate change, mentioned above, be caused by known physical, chemical and biological processes relating to solid Earth, its hydrosphere and atmosphere or its orbital motion around the Sun, assuming that the solar energy output is constant?

2. Methods and overview of subsystems and processes

2.1. Activities

To reach an answer to the question above, the following activities have been performed:

1. Extension of subsystem and process knowledge in the climate system with emphasis on supporting observational evidences.
2. Formulation of risks involved in analysing incomprehensible systems.
3. Design of a preferred simple flow model based on results from Part II.
4. Confronting the proposed model with observational evidence involving:
 - periods longer than 1 million years
 - periods 10 thousand to 1 million years
 - periods 1.5 years to 1 thousand years
5. Formulation of deductions and statements

The result from (1) is presented in II:2–9 and the one from (2) is presented in II:10. The proposed global energy flow model will be presented in III:3. Climate variations over a large frequency range is adress in III:4–6. Summary, conclusions and statements can be read in Part IV.

2.2. Methods and considerations

The basic assumption will be that energy is indestructable and that the main supply of energy controlling the climate on Earth originates from the Sun shining with a constant effect. The existence of tidal effect from both the moon and planets is taken for granted even if the magnitude of transferred effect is small. The possibility that tidal effects can trigger redistribution of energy in the atmosphere and oceans, is seriously considered. The basic principle in the main model is thus to describe and examine the most relevant energy flows entering and leaving Earth's atmosphere, and their controlling functions.

Earth's climate will be treated as an incomprehensible system which has been proven to produce climate effects that range from weeks to millions of years. As such, the system can partly be understood by establishing as many subsystems as possible as comprehensible to lessen the number of incomprehensible subsystems.

Regardless of this work, many subsystems will stay incomprehensible. Knowledge of these systems can be extended by massive accumulation of input and output data, preferably in the form of time series which has been stressed above. Another way to extend knowledge of IS is to use analogy reasoning. This method will not make an IS understandable in terms of cause and effect but it might be able to isolate the response of a subsystems, thus reaching towards a better understanding of the main system function.

Simple models will be used for testing the sensibility to variables. There are no claims here that such a model will be true in a strict sense but the result should be considered as probable based on common sense. To be worth a scientific acceptance these model results have to be supported by observational evidences.

As have been pointed out, the input and output signals can very seldom be measured directly and have to be represented by proxy variables. Some proxy variables are better than others concerning the accuracy of the transfer function from proxy to prime variable. The proxy variables used here will be chosen in a way to minimize the risks if such a choice is possible.

To reach knowledge and to confirm models of an incomprehensible system, the fundamental requirement is access to observational evidences. Regarding Earth's climate this can only be done by using the existing multitude of relevant observations gathered by skilled scientists regardless of their discipline. Since all that information can not be found and put together by a single individual or a group of individuals it is just to pray that the selection made in this work is good enough to contribute to a better understanding of climate change on Earth..

2.3. Major processes involved

Below is an overview of processes treated in Part II.

Atmospheric surface temperature mass dependence

The absolute amount of atmospheric mass might directly control the surface temperature on Earth.

Adiabatic lapse rate

A solar heated surface induces vertical advection of air masses and contributes to establish an adiabatic (temperature) lapse rate in the troposphere. This

process is especially important in combination with the Tibetan Plateau.

Horizontal density forcing in atmosphere and oceans

This physical force is created by the rotation of Earth in combination with density differences on constant gravity potential surfaces. It is responsible for major circulation systems in both the atmosphere and in the oceans.

Subsidence energy transfer

Energy can and does move from the inversion layer in the atmosphere to the ground level, thus increasing received energy beyond that directly received from insolation. This process is most important in high pressure cells and during interglacial times in NH.

Vertical eddy mixing in both atmosphere and oceans

Vertical mixing of gas in the atmosphere, water in lakes and oceans depend on several causes of temporal and spatial ranges from the smallest to the largest. Of special importance is mixing of air and ocean water under the influence of winds and currents.

Energy transfer from the atmosphere to space

Earth is radiating infrared effect close to what is expected from a "black body" radiator. Still, there might be unknown physical mechanisms that can modulate the outgoing infrared emission.

Vertical transfer of air and isotopes in the ocean top layer

This layer represent an anomalous zone of the ocean in a physical, chemical and biological sense. ^{18}O and ^{13}C will be payed special interest since they are used as important tracers and as proxy variables.

2.4. Major subsystems involved

The role of energy storage and circulation systems have already been emphasized as important. Here some old concepts will be revised and some new will be created.

The Hadley circulation system

The basic forces causing the Hadley circulation are discussed and it is made probable that the interaction of the rotating Earth and HDF might be as important as solar insolation.

Ocean surface energy transport

There is a need for continous interhemispheric, ocean bound energy transport to NH during both interglacials and glacials in order to balance ocean bound sensible heat storage.

The monsoon forcing mechanism

The combination of summer insolation in NH, the existence of the Tibetan Plateau at high elevation and the adiabatic temperature lapse rate are the three basic requirements to create a powerful interhemispheric effect exchange

system.

Interhemispheric atmospheric energy exchange

An unrecognized large scale transfer of atmospheric mass and energy from the area covered by the circumpolar current to subpolar areas and midlatitudes in NH is a prominent feature during boreal mid-winters, preferentially during interglacials.

Major energy sinks in the oceans

Types and locations of energy sinks and physical mechanisms for cooling ocean waters are discussed.

Oceans as an energy reservoir

Ocean is the media on Earth that can store large quantities of energy (warm or cold) for periods spanning thousands of years. Thus, it has to play a central role in the waxing and waning behaviour of ice ages.

2.5. Submodels used

The models below are mainly used to get an idea of the sensitivity of an incomprehensible system regarding a specific variable assuming that the incomprehensible subsystem influences stay constant.

Atmosphere energy transmission model surface-space

Often the Earth's atmosphere is considered an ideal "black body" radiator. This simple assumption makes it possible to calculate an average mean surface temperature on Earth between Holocene and LGM. It also implies that the maximum effect of infrared radiation from Earth will be emitted at a mean temperature around -18°C .

Energy age model

By applying a mean "age" to different types of energy it is possible to quantitatively restrict energy storage in both the hemispheres.

Earth hemispherical imbalance concerning energy storage

The areas of Earth, covered by land, ocean and ice introduce an imbalance in the energy storage between the hemispheres if the energy "age" model is correct. This imbalance seems to be fairly constant during interglacials and glacials.

Subsidence effect model

This model describes how sensible heat above the inversion layer will reach the surface of Earth in a quantity that is comparable to solar insolation values.

Forced convective heat transfer model

In this model the outgoing infrared effect is related to the absolute surface mean wind speed over the oceans.

Diffusion / vertical eddy mixing model in ocean surface layer

This model combines gas mixing processes, kinetic isotope diffusion, biological

isotope differentiation and wind induced vertical eddy mixing to explain variations of ^{18}O and ^{13}C in deep sea cores.

2.6. Unavoidable problems with proxy variables

Inadequate interpretation of proxy variables is probably the main reason why the immense amount of gathered records have not led to a break through in climate research. Here, some of these problems have to be addressed since they are included in so many articles, deductions and data, that comments have to be made. Some of them are mentioned below.

Dating with ^{14}C isotope

The main assumption relating to ^{14}C -dating, is the constancy of $^{14}\text{C}/^{12}\text{C}$ in the atmosphere or ocean. This ratio is not constant because of many reasons. It does depend on the mean absolute surface wind speed above lake, sea and ocean surfaces. Thus, there is an inherent uncertainty in ^{14}C -ages that can not be avoided without detailed, elaborate work to compensate for many factors, if possible at all.

^{18}O as an ice volume indicator

The use of ^{18}O as an proxy value of global ice volume is questioned regarding how much of the amplitude that actually represent ice volume changes (III:5.2). The foraminifera (or other organisms) that procure ^{18}O values constitute themselves incomprehensible systems living in changing environments.

Dependence between ^{18}O and ^{13}C in benthic foraminifera

Interrelationships between species and isotopes based on observational data confirm that the interpretation of ^{18}O as a quantitative proxy for ice volume changes, is not secure.

3. Proposed energy flow model

3.1. Main features of the model

The suggested model is shown in Fig 4. It is schematic, but it does show the essential parts of the climatic energy flows. The purpose of designing the model is to (1) identify main subsystems and processes, (2) use it as a reference when discussing observed evidences and (3) to use it as a base for theoretical considerations and discussions.

The climate of Earth is regarded as an incomprehensible system which is partly not understood. The inputs into the system are solar insolation and tidal effects. The outputs are reflected light and infrared emission. To gain information from this system, we should theoretically know sampled input and output signals during long time periods (II:10). Since there are no proxy values for either infrared emission (S_1) or reflected light (S_2) the climate system cannot be handled as a pure "black box" system. Therefore we are forced to examine incomprehensible subsystems and try to deduce the functions of the main system from knowledge about the former.

Fig. 4 shows how solar effect is reflected directly back into space and how parts of it is absorbed by the atmosphere and the oceans. Most of the effect reaching Earth's surface is absorbed by the oceans and the rest will relatively

MAIN FUNCTIONS AND ENERGY FLOWS OF CLIMATE

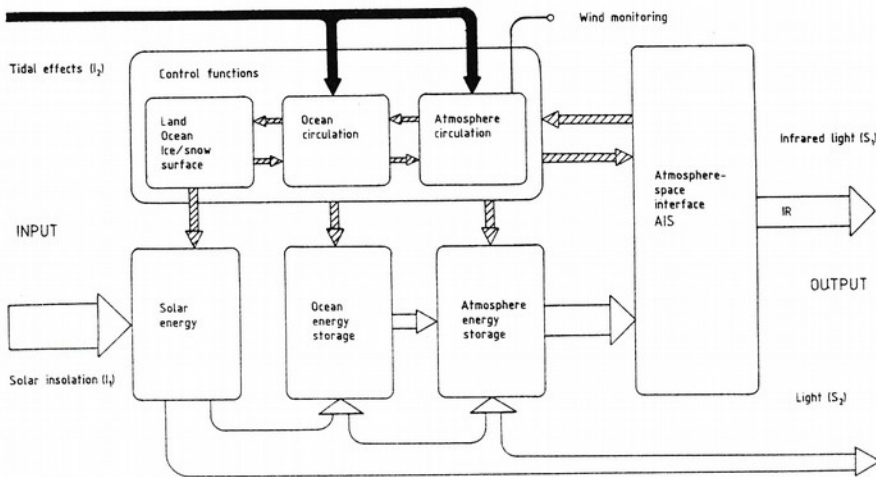


Fig.4. Global energy flow model identifying main subsystems and processes.

soon warm the atmosphere. Since more effect is moving from the oceans to the atmosphere than the opposite way, there is only a one way arrow between ocean energy storage and atmosphere energy storage.

Infrared effect, leaving Earth, should ideally be emitted around an average temperature of -18°C (II:1). A substantial part of it, has to be emitted from a layer of the atmosphere that is at an height of some kilometers, where this temperature prevails in the atmosphere (ASI). Direct infrared emission from land surfaces, is omitted in Fig 4, since it concerns a minor part of emitted effect.

It should be observed, that the feed back mechanisms in the figure only relate to the control functions. One reason is that the most important energy flow feedbacks, take place inside the atmosphere and inside the oceans. The former are represented by NISE (II:5), the Hadley circulation (II:4) and the monsoon circulation.

By control functions are meant any type of process, that can affect climate, without needing much energy input. The change in albedo is one such control which is easy to understand, while stating circulating systems as a control function for climate, might need some explanations.

Tidal effects, is proposed as the second type of input variable, affecting the climate of Earth. The reasons are twofold. Known tidal effects, are produced by forces from outside planet Earth and they do affect ocean and atmospheric circulation systems. This proves that Earth's climate system is not a closed system, defined by matter and processes originating from Earth alone. Secondly it will represent any unknown process originating from outside Earth, regardless of the character of the process.

Let us assume, that there are several reasons for surface winds to blow on Earth. Looking at Earth as an heat exchanger, it is easy to understand that

strong ocean surface winds, favour a transport of ocean energy into the atmosphere and after that into space. The result would be a cooler Earth after some period of time. Any agent increasing mean global absolute surface wind speed, should result in a cooler global climate. Such a process was proposed by Jelbring (1994).

Any process that actually increase atmospheric and ocean circulation (II:6) is a potential cause for cooling the surface of Earth. The tilt of Earth axis can set up larger temperature differences between the hemispheres and thus create stronger atmospheric circulation. Tidal effects might be stronger during certain celestial situations. The infrared emission might depend on unrecognized factors. Tectonic motions might force changes in currents and thus producing more cooling of ocean water etc.

Regardless of the cause to prominent changes in circulation, they might influence climate. This is why ocean circulation and atmospheric circulation have been chosen as control functions for Earth's climate in the proposed model.

3.2. Wind monitoring

Records of effect emission into space from Earth cannot be achieved directly. The most promising proxy variable that can be studied might be wind strength, not only for reasons mentioned above. Eolian sediments, both on land and in ocean cores, can produce good proxy variables for many purposes. The risk of misinterpreting them is small, since they are mostly free from biological processes after sedimentation. In this respect, grain size, per cent eolian sediment, per cent sea salt, etc, are excellent as proxy variables.

Winds can be of local, regional and global character. There are ways of separating these types from one another. Graines, less than 3 microns, can stay many weeks in the air and are usually precipitated together with rain or snow. Sea salt grains in the Vostok ice core belong to this category. Vostok, 1,000 km from the nearest coast, has received sea salt from the oceans. There are reasons to believe that these variations represent a mean global absolute surface wind speed. It is of interest to compare the sea salt (sodium) variations and the ^{18}O isotope from Vostok's ice core shown in Fig. 5 (modified from De Angelis, 1987). It is suggested here, that observational evidences from Vostok ice core, support the proposal that sea salt in the core constitutes a good proxy for mean global absolute surface wind speed, or alternatively a proxy for mean SH surface wind speed.

A third good reason to pay attention to winds are the fact that all stored energy in the oceans has to pass the atmosphere on its way into space. Many atmospheric circulation conditions are registered by the eolian content of sediments. In this way winds are a proxy for energy flows in the climate system of Earth, maybe the best as a substitute for the lacking records of infrared emission leaving the climate system and Earth.

3.3. Model constraints

The following constraints will be considered as valid when discussing the model functions relating to observational proposals and theoretical evidences.

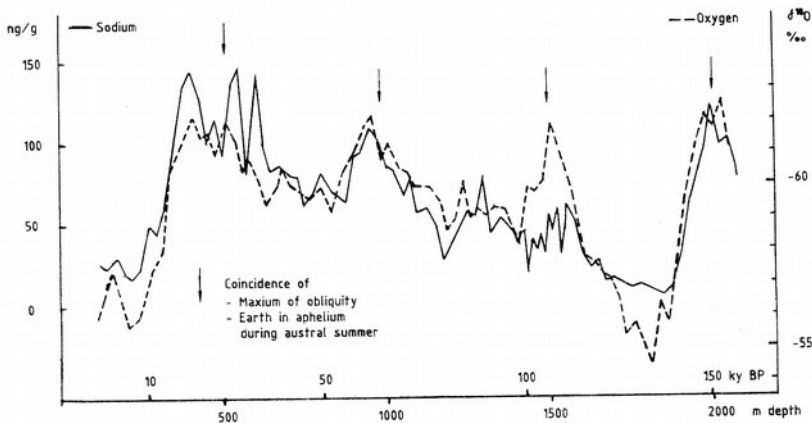


Fig. 5. Proxy variables for SH tilt (41 ky) and global wind strength (100 ky) variations.

(1) There exists an imbalance of stored solar energy between the hemispheres both during the Holocene and during glacials, according to II:2.

(2) The global strength of ocean circulation depends heavily on the production of cold water in combination with horizontal density forcing (II:3). The most important sinks for ocean sensible heat are the Antarctic ice shelves and the northernmost Atlantic and the GIN sea. The latter puts the Atlantic Ocean in a special position as a carrier of warm water to this energy sink area.

(3) The mean global temperature difference between Holocene and LGM is considered to be around 4°C (II:1).

(4) Interhemispheric effect transfer, via atmospheric subsidence, is considered a fact (II:5).

(5) Continuous interhemispheric effect transfer, via the equatorial Pacific Ocean, Cape Agulhas, equatorial Atlantic Ocean and the Gulf Stream, is also considered a fact (II:2).

(6) The interhemispheric effect transfer enhancement, depending on the height of the Tibetan Plateau is considered a reality during both Holocene and glacials, but might be weakened because of an extensive snow cover during the latter.

(7) The Hadley circulation is assumed to increase in strength during glacial conditions (II:4)

With the model of energy flows according to Fig. 4 and the constraints given above, we are ready to challenge the model with observational data and deductions. The information often originates from proxy data time series, often extracted from deep ocean sediments. The fact, that a specific climate process, usually produces variations in a limited frequency range, favours the search for knowledge by splitting observational evidences into frequency categories. We will thus consider climate periods, larger than one million years, shorter than 50 thousand years and one category in between.

4. Long term climate variations

4.1. Life and climate

The most minute type of life forms seem to have had a profound impact on Earth's evolution. The aspects span from the development of free oxygen in the air to the building of mountain ranges. Many minerals, although void of carbon, have actually been precipitated with help of bacteria or other organisms.

Another aspect of life and climate is the importance of life forms as proxy variables for climate conditions (II:10). The existence or non existence of a particular species is a good and common proxy, used for many purposes. A more detailed information is often accomplished by extracting information from isotope data in sediment cores, preferably carbon and oxygen isotopes. These isotopes have almost certainly been involved in the interaction between inorganic substances and life forms on Earth. For this reason, isotope data often involves interpretation problems accompanying biological incomprehensible processes added to other physical and chemical processes, also often of a complex character.

We can hardly avoid the impact of life forms, when dealing with carbon minerals, is shown in an article by Holland (1997) who makes a survey of organic carbon in rocks older than 3,000 million years. The measured depletion of ^{13}C in the sediments, is about -30‰ relative PDB or more, which is a very strong indication of the biological fractionation process and thus indicates the existence of life. This issue is discussed in detail by Schidlowski (1988). Very nice Proterozoic sediment time series of both organic and carbonate ^{13}C isotopes from Greenland and Spitzbergen have been extracted by Knoll et. al. (1986). Both the ^{13}C time series show secular variations but the difference between them only varies a little around -30‰. Life has, indeed, been around for a long time on Earth.

Physicists claim that Sun's effect output is increasing with time, implying that Earth's oceans would have been frozen 3.8 billion years ago. Kasting (1993) does not question the physicists and runs into trouble explaining the old remains of life in sediments, presumably ocean ones. Here, Kasting have a strong case questioning the validity of the theoretical understanding of long term solar effect production. Whatever the answer is, the point here claimed is: Life forms have existed since the oldest time from which we can record data and we have to include influences from life processes when interpreting these data.

4.2. A survey of ancient temperature records

An ice age is usually thought of as an indication of global or possibly hemispheric temperature decrease on Earth, physically manifested in the piling up of ice on Antarctica, Greenland and NH continents. Brechley et. al., (1994), have a somewhat different perspective, when declaring that they recognize three distinct glacial periods. The Permian-Carboniferous one lasted 50-60 millions years and the prevailing glacial period has been going on since 35 millions years. As a little accident there has also been an Ordovician one lasting 0.5-1 million years. Obviously, Brechley et al. mean, that any existing ice accumulation over a long time period on Earth, defines a glacial period. Anyway, they are rare and have not been the average climate condition on Earth since Archean times, regardless of the definition of a glacial period.

Histogram of carbonate ^{18}O isotope data, spanning periods from Archean to Tertiary, have been compiled by Veizer (1976) and they do show maximum values during Tertiary and Permian-Carboniferous. Long term variations in the oxygen isotope might be a proxy for long term temperature changes. This is also illustrated by ^{18}O data from deep sea cores south of New Zealand, spanning the time interval from Upper Cretaceous (Margolis, 1977) to contemporaneous time. A global temperature optimum 53 millions years ago has been followed by a slow cooling at a relatively constant rate until a sudden drop around 35 million years ago. Then the temperature has stayed fairly constant until the middle of Miocene, when it dropped again and finally there occurred a prominent drop around 2.5 million years ago.

Velichko (1989) used mostly palynological evidences to derive temperature data from the southern Russian Plain since Jurassic. The temperature were rather stable during the Cretaceous ($+22^{\circ}\text{C}$) reaching an optimum of $+30^{\circ}\text{C}$ during Eocene 45 million years ago. 30 million years ago there was a substantial drop to about $+18^{\circ}\text{C}$ and since then the temperature has been monotonically declining to reach an early Pleistocene temperature of $+2^{\circ}\text{C}$. Glacial values have reached down to -5°C .

High resolution data, from the South Atlantic Ocean show a sharp change in ^{18}O and ^{13}C at the boundary between Eocene and Oligocene (Zachos, 1996). Miocene glacial ice have been found and identified in East Antarctica (Sugden, 1995). Hodell (1991b) have interpreted isotope variations from site 704 in the South Atlantic Ocean during the last 10 million years. Detailed Miocene ^{18}O and ^{13}C isotope data from *Cibicidoides kullenbergii* from the same site, has been extracted by Müller (1991). These data have all been interpreted as showing a monotoneous (but steplike) decline of global temperature during the Miocene.

There are many articles written about the cooling events and glacial advances that occurred around 2.5 million years ago. Among these are isotope data from subarctic South Atlantic (Hodell, 1991a, Froelich et. al., 1991), Bay of Bengal (Chen et. al., 1995), Norwegian Sea (Jansen et. al., 1989, Heinrich, 1989), North Atlantic (Dwyer et. al., 1995) and Greenland (Funder, 1996). Mörner, (1993) has presented aspects on tectonic motion (uplift of the Tibetan Plateau) and the onset of glacials. Several of the authors do propose that severe glacials affecting NH, were initiated around 2.5 million years BP and that glacials were rare or less severe before that time.

4.3. Other indications of a global cooling since Eocene

The accumulation of sediments, here called drifts, between Greenland, Iceland and Ireland have tremendous dimensions and constitute a proxy variable for the bottom current strengths. Knowledge about these deposits have been excellently presented in Wold (1994). Total sediment mass, accumulation rate and the dynamic evolution of new drifts have all been documented. The general picture is, that the accumulation of drifts started about 35 million years ago. Bottom current induced sediments have been building up the Feni Drift, at an approximately constant rate for about 17 million years. At that time, Björn and Gadar Drift developed and the accumulation rate was doubled. Later on Haton Drift and Snorri Drift were formed. About 5 million years ago the accumulation increased drastically when large deposits were accumulated in

Gadar Drift and the newly formed Erik Drift. A slight decrease from this maximum of accumulation rate might have occurred during the Pleistocene.

The dynamic building up of the drifts, during a period of 35 million years, is telling us the story of an ever increasing importance of the GIN sea and the northern North Atlantic as a heat sink for warm ocean water. The mean accumulation rate has steadily increased even if there exist secular variations, coupled to celestial parameters. An interesting and careful investigation of spectral characteristics of accumulation rates in the drifts have been performed by Robinson et al. (1994). During the period 0.85-1.2 BP, for example, the noncarbonate silt fraction of sediments showed the 19, 23, 41 and 125 ky periods in spectra. The accumulation of the drifts is also an example of the increasing importance of HDF (II:3), being a result of increasing density differences accompanying severe cooling in the GIN sea.

If mean global temperature depends on mean global absolute wind speed, there would be an increase in wind speed since 20-30 million years. Such an increase has actually been documented from a Pacific Ocean core in the middle of the ocean (about 30°N, 155°W). Eolian grain size (1-3 microns) and percent eolian quartz have been used as proxy variables. Both show a steady increase since around 30 million years ago (Rea, 1985, Fig.2) indicating a steady increase in mean global wind strength since that time.

4.4. Cyclic variations in proxy variables

A cyclic stratification pattern in ocean sediments is a rule, not an exception relating to cyclic changes between glacials and interglacials. Are Pleistocene Milankovitch cycles produced by the same agents as the cycles hundreds of million years ago? Let us try to find an answer and start with the existence of Lunar tidal effects. They seem to have existed since at least a billion years (Sonett, 1996), even if the day, at that time, lasted only 18-20 hours.

Seasonal and decadal climate variability existed during the middle Pliocene according to data from a fossil coral from southwest Florida. A conservative interpretation of isotope proxy data, shows that the mean seasonality (seasonal SST range) at that time was 7.0°C compared with 10.5°C during Holocene conditions (Roulier, 1995).

A lacustrine equatorial sediment core from Late Triassic, has been investigated using a sophisticated method. The sediment samples have been dated, relating to the depth of the lake, and signal processing technique have been applied (Olsen, 1996). The paleolake is named the Newark Rift Basin and is situated in eastern North America. The core reached a depth of 6770 m covering a time span of 22 million years. All Milankovitch frequency components are claimed to be found with the strongest being around 100 ky. There were no massive glaciers on Earth during Triassic.

Milankovitch type variations have been identified in Lower Cretaceous sediments from western central Atlantic Ocean and from the Vocontian Basin in France (Huang, 1993). The two time series cover around 5-6 million years each. Varying frequencies between 20-175 ky have been produced. Certain time series show almost a single frequency between 40-51 ky indicating influence from a varying tilt of Earth's axis.

An interesting article couples variations in orbital eccentricity during

Cretaceous with deep-sea anoxia (Herbert, 1987). The core is from the southern side of the Tethyan seaway at a paleolatitude around 19°N. One conclusion is, that minimal eccentricity produced the anoxia, that is to say, ocean deep-sea circulation in an ice free world depended on the eccentricity of Earth's orbit around the Sun. If this interpretation is correct, which physical process produced that dependence?

The cyclicity in Cretaceous sediments is coupled to variations in the ^{18}O isotope (Ditchfield, 1989). A core taken from the Dover region in southeast England shows very regular isotope variations between marl and chalk in the sediments. The ^{18}O isotope varies between -3.3‰ to -2.4‰ with the lighter isotope values belonging to the chalk. The favoured interpretation of the isotope variations, is as a proxy for a bottom water temperature increase of 4.5°C, when chalk precipitated.

An investigation of a 16 my long Miocene ocean core, record *Coccolithus pelagicus* abundance from ODP site 747 in southern Indian Ocean. Some interesting conclusions have been expressed (Beaufort, 1994). The amplitude of the main signal with a period of 111 ky, fluctuates quasi-periodically, modulated by periods of 2.38, 1.14 and 0.8 million years. These modulations are assumed to be identical to modulations of the orbital eccentricity. It is also claimed that the amplitude of the 111 ky cycle is stronger during cooler geological time periods. As a fact, the sidereal period of the perihelium position of Earth is 111. ky. The signal might depend on changing global wind strength with that cyclicity influencing the planktonic assemblages, and thus the sediments.

Nonstationary behaviour in climate cycles, has also been recognized in the phase of Asian monsoons during Pliocene to Pleistocene (Clemens et al., 1996). The identified 23 and 41 ky cycles have changed phase relative "global ice volume" inferred from marine oxygen isotope records. One conclusion is, that monsoon variations and global ice volume changes are both nonstationary processes relative orbital (insolation) forcing.

Few time series are based on eolian information but there are some. ODP site 659 (18°N, 21°W) is situated around 500 km from the African east coast and eolian sediment will directly register variations in trade winds and in the African easterly jet stream (Tiedemann, 1994). Spectral analysis has been performed on dust flux and ^{18}O data during 2.85-4.45 BP. Spectral analysis before tuning does not give any useful results but the spectral characteristics after tuning are amazing. The ^{18}O isotope variations are dominated by the 41 ky cycle, but the dust flux record is dominated by the 19, 23 and 100 ky components and is almost lacking the 41 ky component. *This means that the processes generating the African dust flux variations (wind strength and wind direction) and the ^{18}O variations are approximately uncorrelated.* The processes are probably quite different and might be possible to identify.

4.5. Transient variations in climate

Some climate changes do not belong to a cyclic or quasi-cyclic type of variation. They might be the most violent and catastrophic events that have plagued life on Earth, sometimes involving the extinction of large parts of the flora and the fauna. They are often the reason for naming periods in the geological time scale. Many hypothesis exists for their origin. We will just mention some observational evidences coupled to these transient events.

In an intricate investigation of rocks from Spitsbergen, Italy and Slovenia, Wignall et al. (1996) suggest that the oceans of the world became anoxic at and after the Permian mass extinction. The boundary is registered by strong ^{18}O and ^{13}C deviations constituting two pulses. The first one, the most intense one, covers about 10 m of a 330 m marine drill core (Carnic Alps in Austria, Holster et al., 1989) closely after the Permian-Tertiary boundary and the second one spans another 10m, 30 m above the boundary level.

Three major geological boundaries also register transient ^{13}C isotope variations (Precambrian/Cambrian, Permian/Triassic and Cretaceous/Tertiary, Magaritz, 1989). A high carbon isotope value suddenly drops 3-4‰, followed by a slower return (not complete) during a considerable time span. Strong evidences indicate that the changes are world wide.

A peculiar event, involving mass extinction of benthic but not planktonic foraminifera, occurred near the end of Palaeocene (57 my BP). The event was registered by ODP 690B drill core, Maud Rise, Antarctica (Kenneth et al., 1991). Both ^{18}O and ^{13}C isotope values dropped sharply to recover in an almost linear fashion during 300,000 years. The oxygen isotope recovered somewhat faster and more completely than the carbon isotope. The isotopic changes are claimed to indicate a global warming. Another interpretation that should be considered is gigantic volcanic activity in the oceans that polluted the bulk of ocean waters but let the surface bound life forms survive.

4.6. Summary and conclusions regarding long term climate change

Catastrophic events have hit Earth and influenced climate. Still they are rare and in between these events other mechanisms control the climate. Of special interest are the responses, registered by isotopes, from such events. These are probably a function of complex interactions between Earth's atmosphere, hydrosphere and biosphere. This means that an understanding of the causes of the variations might be far away. It does say, that isotope data might have three main causes being (disregarding specific species effects), temperature dependence, global ice volume dependence and biosphere-atmosphere-hydrosphere interaction dependence. The last one is regarded to be of an incomprehensible nature and the second one is regarded to be quantitatively insecure.

Cyclic climate changes always seem to have been around, regardless of Earth's surface temperature. During warm periods in Earth's history they seem to have had a relatively minor influence being of smaller amplitude, but still, they have been there. All carbonate rocks in the world bear witness to this fact.

There has existed long term temperature changes on Earth in the range of 20°C or more. A sustained increase or decrease (10:th of million years) in that temperature range could hardly be produced by transient climate shocks or by the celestial parameters influencing insolation.

There is an obvious candidate, in explaining the slowest but also the greatest temperature variations in the climate history of Earth. Variation in solar energy production rate, should be able to produce the observed effect, but there is one more strong candidate. Long term variations in Earth's surface temperature can be produced by variations in the Earth's atmospheric mass

(II:7). A detailed discussion of pro and cons relating to these two hypothesis will not be performed here but some evidences will be mentioned.

By analogy, what can happen on Venus can happen on Earth. Venus surface temperature is around 480°C and the atmospheric mass surface density is 90 times the one on Earth. This implies that the surface temperature of a planet might be a function of its atmospheric mass.

Secondly, the atmospheric mass on Earth has experienced pronounced changes. Just as an example, consider the amount of carbon that is stored in carbonate rocks. Most of this carbon has been transferred from the atmosphere to organisms (usually living in the ocean surface layer), and has once been in the form of atmospheric carbon dioxide. The amount of stored sedimentary carbon, is equivalent to at least 20 of our modern atmospheres, filled by 100% carbon dioxide! There is no sound reason to assume that the Earth's atmospheric mass have stayed constant through geological periods, thus these changes must have influenced surface temperatures on Earth according to II:7. Since the atmospheric mass changes have been varying slowly, the temperature changes should show up as long term variations in Earth's surface temperature.

Perhaps the strongest observational evidence, for long term temperature changes on Earth, is given by Knauth and Epstein (1976) in an article titled "Hydrogen and oxygen isotope ratios in nodular and bedded cherts". Although there are alternative hypothesis regarding explanations to the large temporal isotope variations found in cherts, the authors' arguments are persuasive. They originate from rain water and depend on changes along the meteoritic waterline and the temperature when chrysalization occurred. In this case the cherts are from central and western U.S. The authors claim a temperature decrease from 34°C to 20°C through the Paleozoic, an increase to 35-40°C in Triassic, and then a monotonic decrease through the Mesozoic to Tertiary values ending around 17°C. They also suggest values of 52°C 1.3 billion years ago and around 70°C 3 billion years ago.

Knauth's and Epstein's paper does not discriminate between any specific cause of the deducted temperatures. A reason why their paper have not been paid the attention it deserves, might be the lack of an acceptable physical process producing the temperature changes. Such a process is suggested in II:7. It is here strongly suggested that these temperature changes, in the first place, were caused by *variations in Earth's atmospheric mass*.

4.7. Model considerations

There are no direct reasons to believe that known or unknown tidal effects produced the observed long term climate changes. The model also omits the influence from catastrophic events like meteoritic impacts or large scale (oceanic in the first place) volcanic activities since they, although violent, produce transient effects that will die out and only directly influence Earth's climate during a small time on a percentage time base (excluding atmospheric mass changes by vulcanism). Milankovitch variables seem to have had an influence on Earth's climate during all geological periods, but with smaller amplitudes during warm climate periods. Thus, they should not be the cause of the large, long term variations of Earth's climate, that have actually been recorded by many scientists applying different methods.

In this perspective, the existence of an atmospheric-space interface (ASI) with a fairly constant density can explain large surface temperature variations on Earth, despite a constant energy output from the Sun. It is an intraclimatic effect in the first place, since it can occur without changing input and output signals at all (Fig.4). It only involves subsystem changes, but it specifically influenced the variable which life is most sensitive to; that is the surface temperature of Earth.

The temperature variations due to atmospheric mass variations, are likely to be confined to long term changes in climate. The analysis will from now on, be confined to changes during the last million years BP, and during this time the atmospheric mass of Earth will be regarded as approximately constant.

5. Glacial-interglacial climate variations

5.1. Some observational evidences

Let us look at observational evidences of climate variations in the time scale 50-1,000 ky before expanding any deeper theoretical aspects on these variations. It is of interest to acquire some opinion of the distribution of cold and warm situations on Earth. DSDP site 607 provides a very good data base, and is situated at a key position (41°00' N, 32°58' W) in the Atlantic Ocean, to monitor ocean energy flows. Fig. 6 shows a number of histogram (all data from Ruddiman et al., 1989), illustrating winter sea surface temperatures based on a four species transfer function F13x5. The temperature data span a temporal range of 1.65 million years. The sampling intervals are varying, as can be seen by noticing the number of samples in each histogram. The total numbers of proxy temperatures are 630. The temporal coverage of each histogram is chosen to recognize the distribution pattern of temperatures during two so called "glacial cycles" of 100 ky each, in the first place.

As can be seen, the winter surface temperature distributions during each 200 ky interval is far from being a normal distribution. This directly tells us that the process (processes) causing the temperature variations are variable in time (time dependant statistics) or involves cycles with periods longer than 200 ky. The most extreme distribution occurs during 651-850 ky BP. This period seems like a transition period to a cooler climate. Histograms from both sides of this period are shown to the right in the figure. These have the characteristics close to a normal distribution.

The median temperature has sunk by 2.4°C between the periods mentioned above. According to II:1 this is 50% of the temperature range between an interglacial and LGM, equivalent to a 3.4% decrease in solar effect. The difference in the two distributions is due to an expansion of temperature variation (standard deviation), keeping the extreme warm temperatures at a constant level. This feature alone, almost exclude solar insolation variations as a major cause to the cooler climate. This observation is important, since the general cooling does not seem to prevent the sea surface to reach the same maximum temperature as before the cooling. If looking for a process producing the presented temperature distributions, it should at least span 500 ky to involve the extremes. Suggesting a specific physical process, changing global wind strength would fit. The warmest period would then indicate calm global wind conditions on Earth.

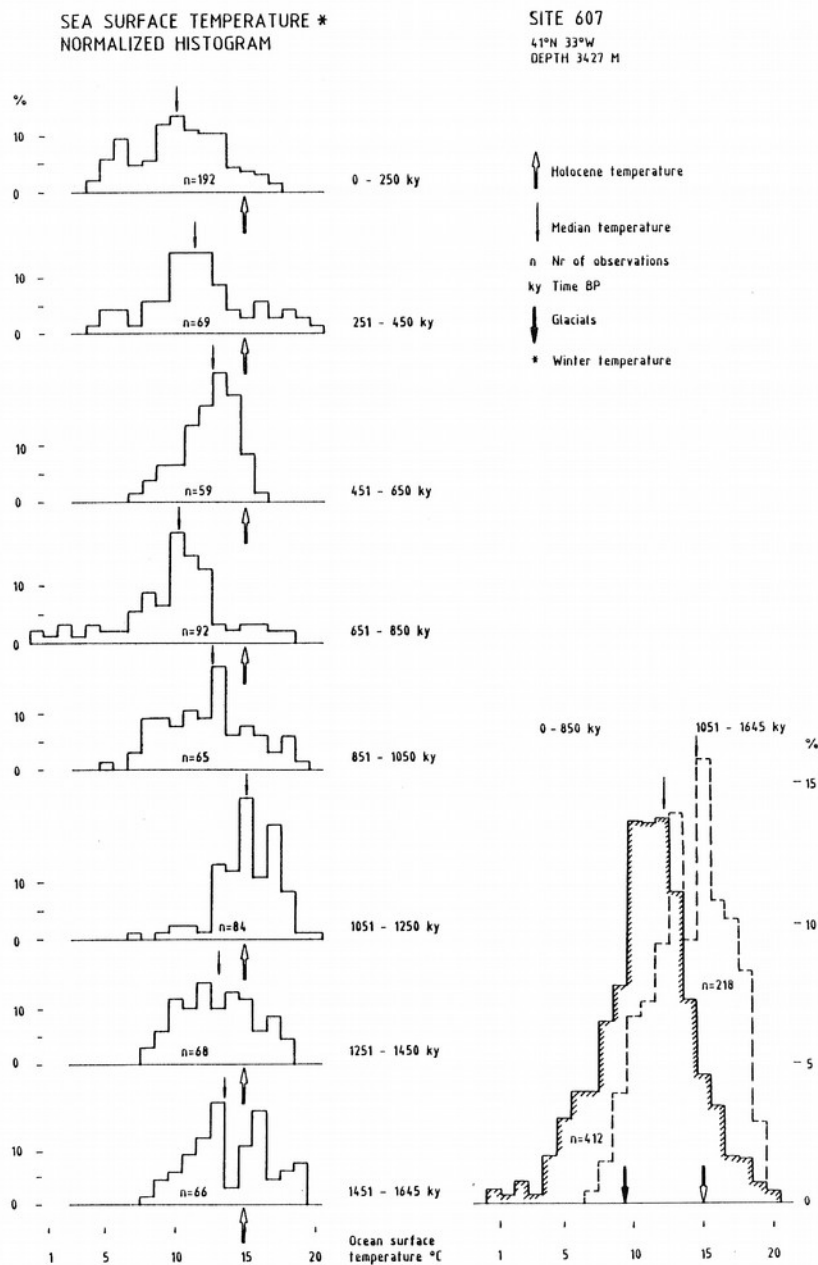


Fig. 6. NH sea surface temperature statistics (Site 607).

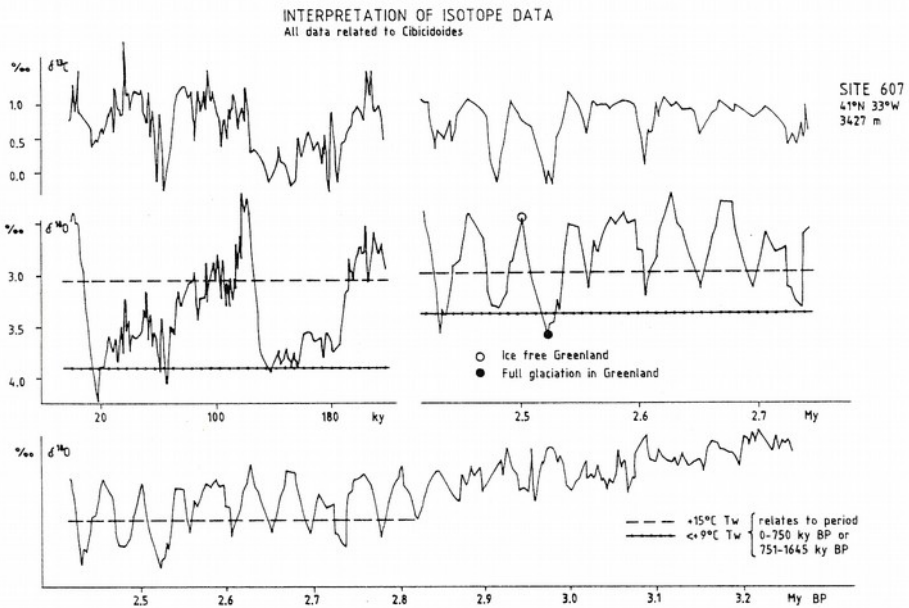


Fig. 7. Long term isotope data as proxy variables.

Staying at the same location, Fig. 7 (modified from Fig.3A by Dwyer et al., 1995), shows oxygen isotope variations during two time periods and a reference to Greenland climate conditions at Cape Copenhagen at latitude 82°N (Funder, 1996). The dashed horizontal lines refer to equivalent Holocene ^{18}O values based on winter sea surface temperatures at site 706 during 0-750 ky BP (left middle) and during 751-1650 ky BP (right middle and below). The line with points indicate full glacial conditions based on winter sea surface temperatures at site 607 during 0-750 ky BP (left middle) and during 751-1650 ky BP (right middle). How these values have been calculated will be explained later. The open circle indicate much warmer conditions than today at Cape Copenhagen and the filled circle indicate full glacial conditions. It is easy to realize, that if the two dotted horizontal lines indicate glacial conditions, then the ^{18}O information is ambiguous as a proxy variable for global ice volume.

The bottom part of Fig 7 shows the oxygen isotope deviations for a time span of more than 700 ky. Funder (1996) claims that the glaciations around 2.5 million years BP were the first severe ones hitting NH. Relating NH glacial conditions to winter sea surface temperatures at site 607 supports his conclusion and casts doubt on the ^{18}O isotope to register accumulated global ice volume in a linear fashion.

Long oxygen records (since 5 my BP) have been derived at the Pacific site 846 and the Atlantic site 659 (Tiedemann, 1994). The latter is extracted from *Cibicidoides wuellerstorfi* (see also Clemens, 1997), a species mainly used also at site 607. If the oxygen isotopes from *Cibicidoides* register the same physical conditions at site 607 and at site 659, which there are reasons to

believe, then by analogy, the climate conditions between 5-3 my BP were at the Holocene level or warmer during about 80% of that period.

Observations, like the ones cited above, have led the author to seriously question the widely accepted concept, that the ^{18}O isotope variations constitute a (linear) proxy for global ice volume. Even if this is not a main topic here it has to be seriously examined relating to the importance of a proper interpretation of isotope data. There are so many and excellent isotope time series from all over the world, and the information they carry should be used to its fullest potential.

5.2. ^{18}O isotope variation as a proxy for global ice volume

DSDP site 607 is located at latitude 41°N (Fig. 8), at latitude crossing the middle of Portugal. The average Holocene winter sea surface temperature during the last 5000 years have been about 15.8°C (9 values). The mean winter ocean surface temperature at this site has varied between 0 and 20°C , a fact somewhat hard to comprehend. The concept *mean* is used since any sample will collect species spanning a considerable time period. A reasonable proposal is that the winter sea surface temperature at site 607 is colder during glacials than during interglacials. Even if the water temperature some times are out of phase with global ice volume, it should be a good average relationship.

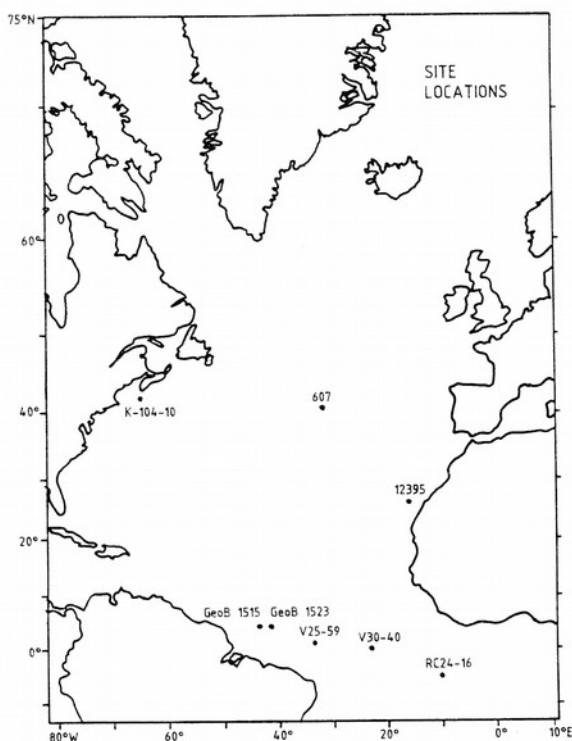


Fig. 8. Location of Atlantic cores.

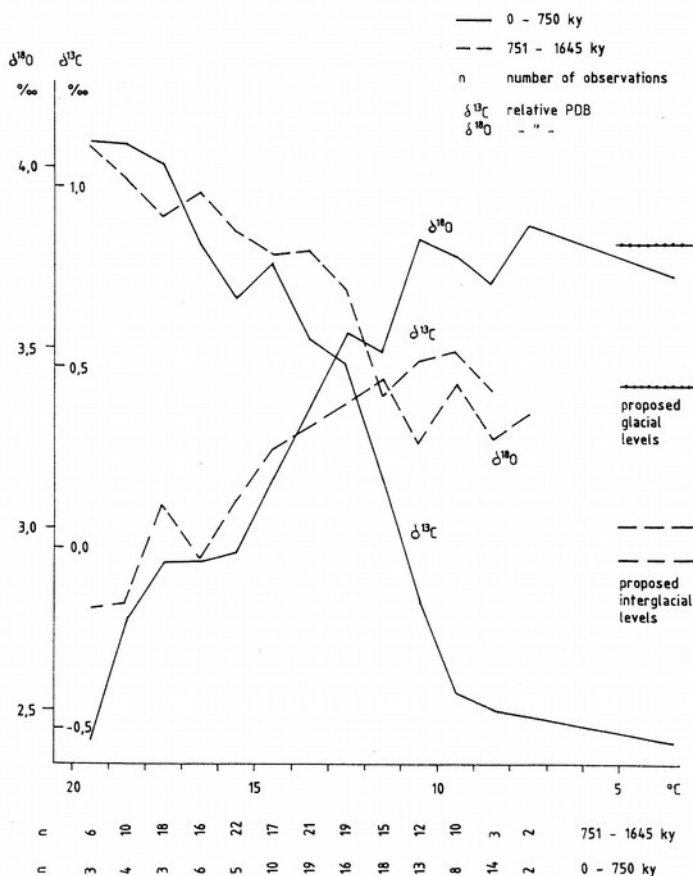
ISOTOPES AS A FUNCTION OF
OCEAN TEMPERATURESITE 607
41°N 33°W
DEPTH 3427 m

Fig. 9. Relations between winter sea surface temperature and isotope data.

If the out of phase situations are distributed equally in both directions around a mean value, the sea surface temperatures at site 607 will be a good proxy for the global ice volume, even if the relationship might not be quite linear. It will here be assumed that the sea surface temperature at site 607 is a proxy for global ice volume.

Both sea surface temperatures (decided from species abundance) and ^{18}O and ^{13}C isotope values from *Cibicidoides* sp. are tabulated in Ruddiman et al., (1989). Some of these values are derived from identical drill core samples. These data are arranged in Fig. 9, so that isotope values are shown as a function of winter sea surface temperature for two major time intervals, 0-750

ky and 751-1650 ky. The number of measured samples within each temperature interval (1°C) is written below the temperature scale. The standard deviation of each temperature value in Fig. 9 is thus 1.5-4 times lower compared with the standard deviation for individual values.

The result is interesting since the two sets of curves differ substantially. This directly make us to suspect a time varying process, the isotopes might show different values for the same physical situation. Looking at the ^{18}O curve for 0-750 ky, it seems like there is a plateau for winter temperatures around 15.5-17.5°C, at an oxygen isotope value of +2.9‰. A similar plateau can be recognized for the older period around +3.0‰. For cold sea water temperatures the isotopes seem to reach maximum at +3.8 and +3.4‰. Both of these values can for good reasons be interpreted as indicating full glacial conditions. The differences between the top values and the plateau values in each set can be interpreted as a proxy values indicating global ice volume change relative Holocene conditions.

This would surprisingly mean different ice volumes at full glacial conditions. The answer to this riddle might be a nonlinear relationship between the ^{18}O isotope and global ice volume. It is quite evident that the isotope values are a function of sea surface temperature, global ice volume and a balance between the biosphere, atmosphere and the hydrosphere which we at this point will declare as an incomprehensible system. The result should lead to some second thoughts. This is the background for drawing the horizontal lines in Fig. 8 and they are indicated in Fig. 9. The reasoning above and information given in Fig 9 can be considered a strong indication of dependances not earlier discovered or at least not pointed out.

There is another way to gain more knowledge about processes changing carbonate isotope values. Isotope values from independent samples have been measured for *Cibicidoides* sp. (*wuellerstorfi* and *kullenbergii*) and *Uvigerina* sp. in 47 samples (Ruddiman et al., 1989). In the same way, isotope values of *Cibicidoides wuellerstorfi* and *Uvigerina peregrina*, have been extracted from 55 samples from the Meteor core 12392 at position 26°N, 16°W. (Zahn, 1986). In Fig. 10 the difference between the oxygen and carbon isotope values for one species has been plotted as a function of the same difference for the other species. As can be seen, the correlation between these quantities are striking. The lines drawn in the figures are based on median values, the same amount of isotope values are positioned on each side of the lines. Both lines have the same gradient but a small value (0.16) separate their crossing of the ordinata.

The interpretation of this relationship is not easy in rational terms. Anyway, there are consequences even if the causes for the relationship is not understood. Assume that the ^{13}C value of *Cibicidoides* is 0.9‰ higher than the one for *Uvigerina* as is recommended (Ruddiman et al., 1989). In such a case the ^{18}O amplitude between Holocene and LGM, measured by *Uvigerina* will be around 0.3‰ higher than the one measured by *Cibicidoides* for identical samples. The relationship showed in Fig. 10 is hardly a local phenomena. It does prove that the interpretation of ^{18}O over long time spans cannot be done correctly without incorporating the interaction between oxygen and carbon in the total system, regardless if it is wind induced, falling organic particle induced

ISOTOPE DEPENDANCE BETWEEN FORAMINIFERA SPECIES

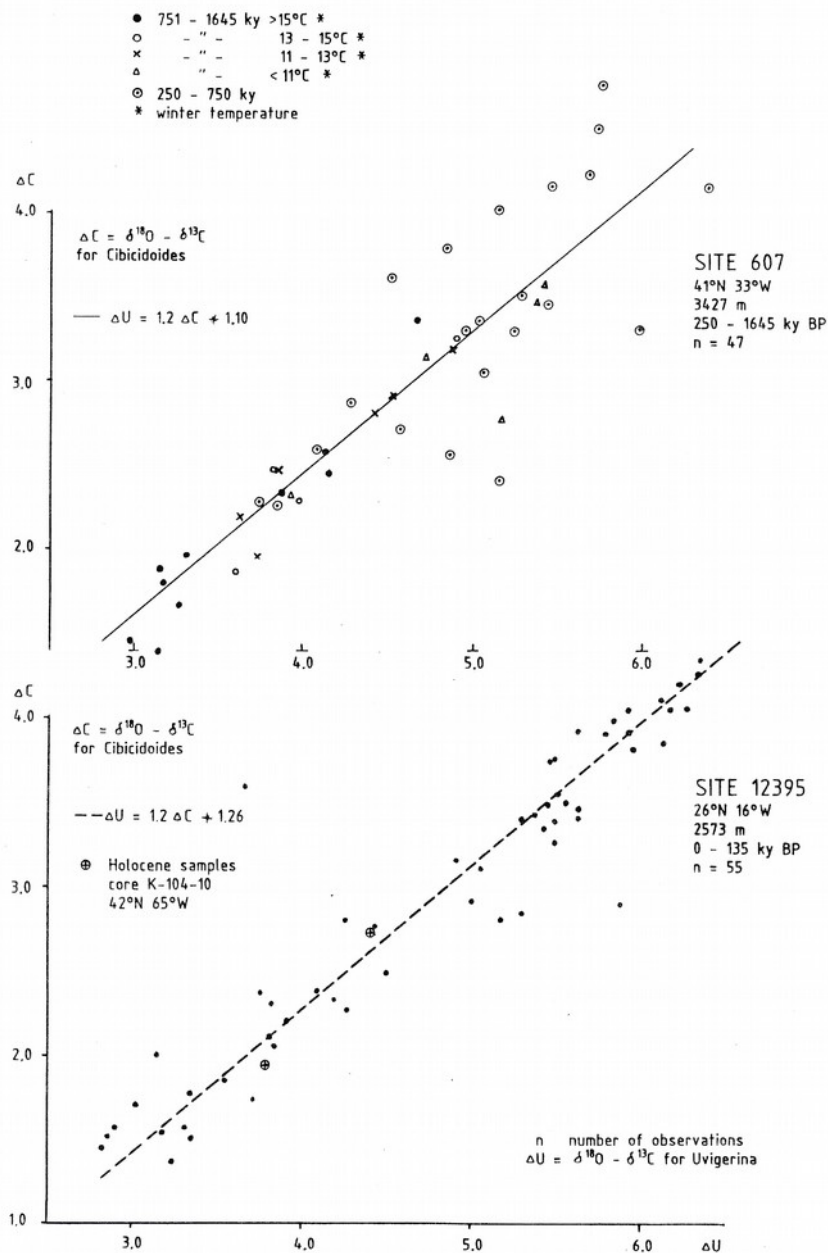


Fig. 10. Inter-species and inter-isotopic dependencies.

or caused by shifting bottom currents. ^{18}O alone is not a good proxy, either for temperature or global ice volume. It does, to a large extent, depend on the complex interactions between the biosphere, atmosphere and the hydrosphere during long time spans.

There are many other observational facts that can be used for criticizing a direct correspondence between ^{18}O isotope deviations and global ice volume. Some will be mentioned.

Oxygen isotope data from core V29-202 (north of 60°N in the Atlantic Ocean, *Cibicidoides wuellerstorfi*) shows a very "flat" structure with almost no precessional cycles indicated during the last 150 ky (Oppo et al, 1995). Here it is suggested that an ice cover most of the time prevented normal interaction between the atmosphere and the ocean surface which made the curve to deviate substantially from the "norm" given by SPECMAP (Imbrie et al., 1984).

Pollen records from two sites in Europe indicate fairly warm climate between 128-74 ky BP (Guiot et al., 1989), including a very small excess temperature during stage 5e contrary to SPECMAP. This indicate that most, if not all, of the high amplitudes during stage 5e and Holocene in SPECMAP's ^{18}O curve might be a transient phenomena, produced by interaction between the bioshere, atmosphere and the oceans.

An oxygen isotope record from Owen Ridge, northwest Arabian Sea, core RC17-98 (Clemens and Prell, 1990) shows hardly any precessional variation during stages 5a-5e. This is suggested to depend on the active influence of the monsoon system causing an almost constant circulation in both the atmosphere and in the ocean surface waters. This observation supports the idea that the ^{18}O maximum part in SPECMAP stage 5e is a transient phenomena independant of the volume of accumulated ice.

An oxygen isotope record from the Red Sea (Hemleben et al., 1996) is congruent with the SPECMAP record but its amplitude is 5‰, four times what is supposed to be caused by ice volume accumulation during glacials. The "extra" amplitude during stage 5e is about 1.5‰ alone. It is here suggested that the formation of the peak in the oxygen isotope record during stage 5a is favoured by calm and warm climate. The ^{18}O isotope range in SPECMAP (Imbrie, et al., 1984) should also be questioned. It spans a range wider than 0.9-1.3‰ which logically should represent global ice volume accumulation. Until this difference is explained in a satisfactory way, the processes producing the oxygen isotope variations should be considered incomprehensible (II:11).

5.3. Observational evidences from the equatorial Atlantic

The Atlantic Ocean is the gate way for ocean-bound hemispheric effect transfer from SH to NH. Since this effect is bound to move northwards during both glacials and interglacials (II:2), the most intense confrontations between different water masses in the oceans should and have to occure around the equatorial Atlantic Ocean which can be predicted using arguments in II:3.. This is why, in the first place, the energy flows and circulation systems, will be exmined in the equatorial Atlantic Ocean.

Fig. 11 provides an astronomical time table, which names and tells the times of some celestial events with a potential to be related to circulation systems on Earth. Times for maximum southern caloric equator (MSCE), its

ASTRONOMICAL TIME TABLE

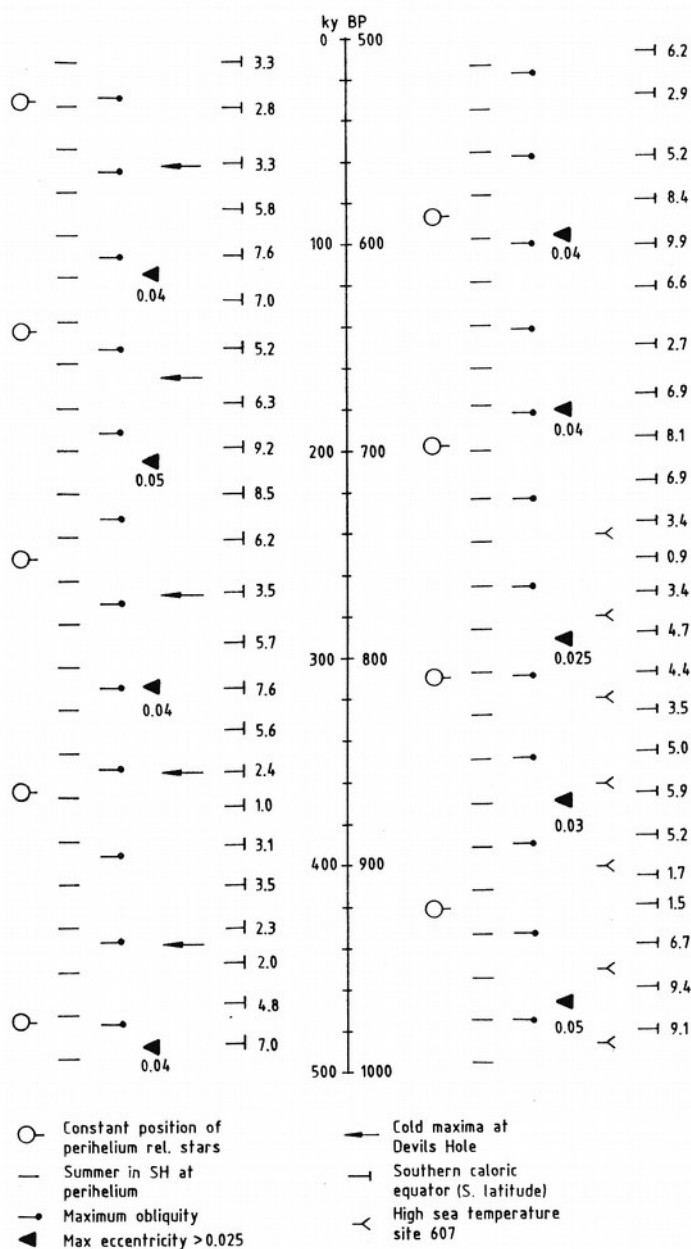


Fig. 11. Astronomical time table and symbols used.

latitude, maximum obliquity and maximum eccentricity are from Berger, (1978). The time of summer in SH at perihelium is calculated assuming constant angular motion of the perihelium and a constant precession rate of Earth, which is only correct to a first order.

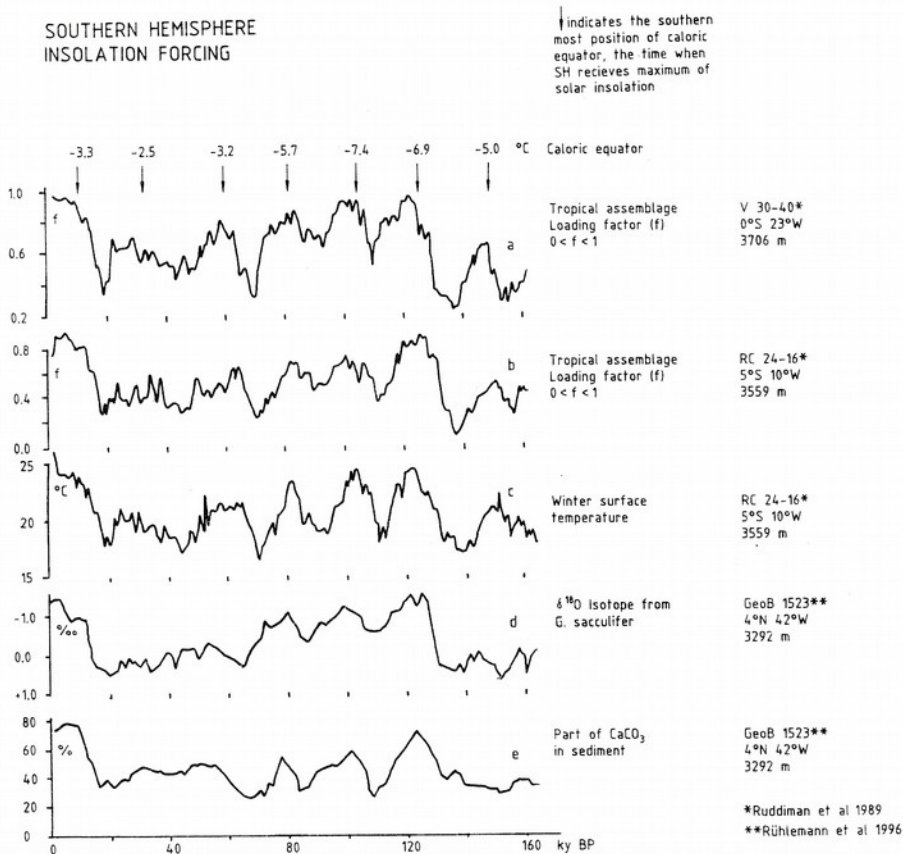


Fig. 12. Proxy variables showing SH insolation variations.

In Fig. 12 some variables are chosen that obviously are related to maximal insolation in the SH. This can be seen by the arrows that show times for MSCE. The maxima in the figures are delayed some thousand years after the occurrence of MSCE. Fig. 12a and 12b show the variation of a quantity called loading factor for a tropical assemblage (a selected group of plankton species). There are four more assemblages (McIntyre, 1989) and the sum of the squares of the loading factors of all four assemblages will always equal 1. If the loading factor for the tropical assemblage is 1, only species in this group will then live in the waters at the site.

DYNAMICS OF OCEAN CIRCULATION FROM 3 ATLANTIC SITES

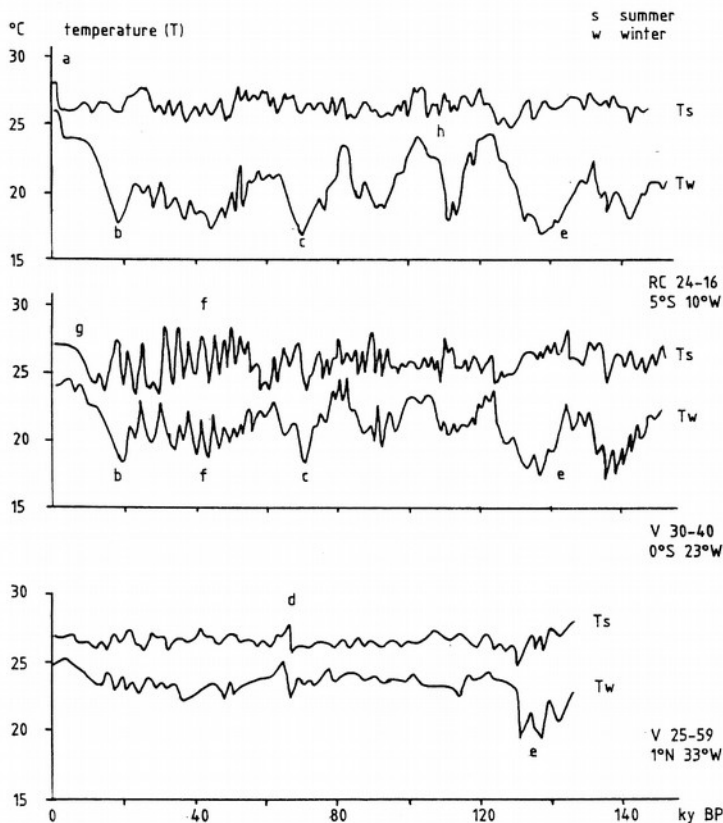


Fig. 13. Examples of observed sea surface temperature responses.

The tropical assemblage prefers calm and warm waters. At site V30-40, west of site RC 24-16 the loading factor is higher but the variations are almost identical. At site RC 24-16 there is more upwelling than at site V30-30. This fact is shown in Fig. 12c showing ocean winter surface temperature variations. As can be seen, the maximum variation in winter SST can reach around 7°C. The type of assemblage dominating the ocean is very dependant on both the atmospheric and oceanic circulation. The loading factor does give good information about the ocean circulation system at the site.

The ^{18}O variations from a planktonic foraminifera and the per centage of carbonate in sediments (Rühlemann et al., 1996) show the same signal structure as the other variables. The objective with Fig. 12 is mainly to show that direct forcing from SH insolation do exist and that it plays a significant role in the equatorial Atlantic Ocean. The delay between MSCE and the maxima of

the curves are around 2 ky. Its implications concerning physical processes will be a later issue.

The surface temperature of the Oceans are thought to be very important. In Fig. 13 both summer and winter temperatures are shown. The differences in temperature variations at the three sites are striking. This will be discussed later. Notice that it is only the winter temperatures at the two eastern sites that show the typical signal structure from Fig. 12 that we are accustomed to recognize from ^{18}O variations in both planktonic and benthic foraminifera.

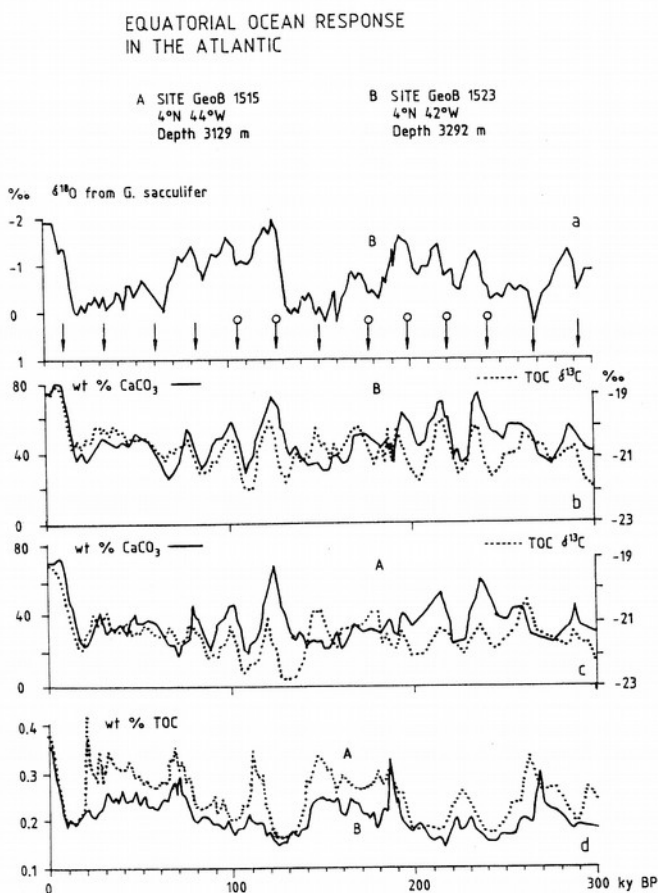


Fig. 14. Responses of proxy variables of climate change.

Fig. 14 provides information from two sites, about 800 and 1000 km from the mouth of the Amazon River. The oxygen isotope record is practically identical for the two sites so only one is shown. Of interest here, is the covariation of ^{13}C in the organic remains in the sediments (TOC) and the per

ATLANTIC SEA SURFACE WINTER TEMPERATURE

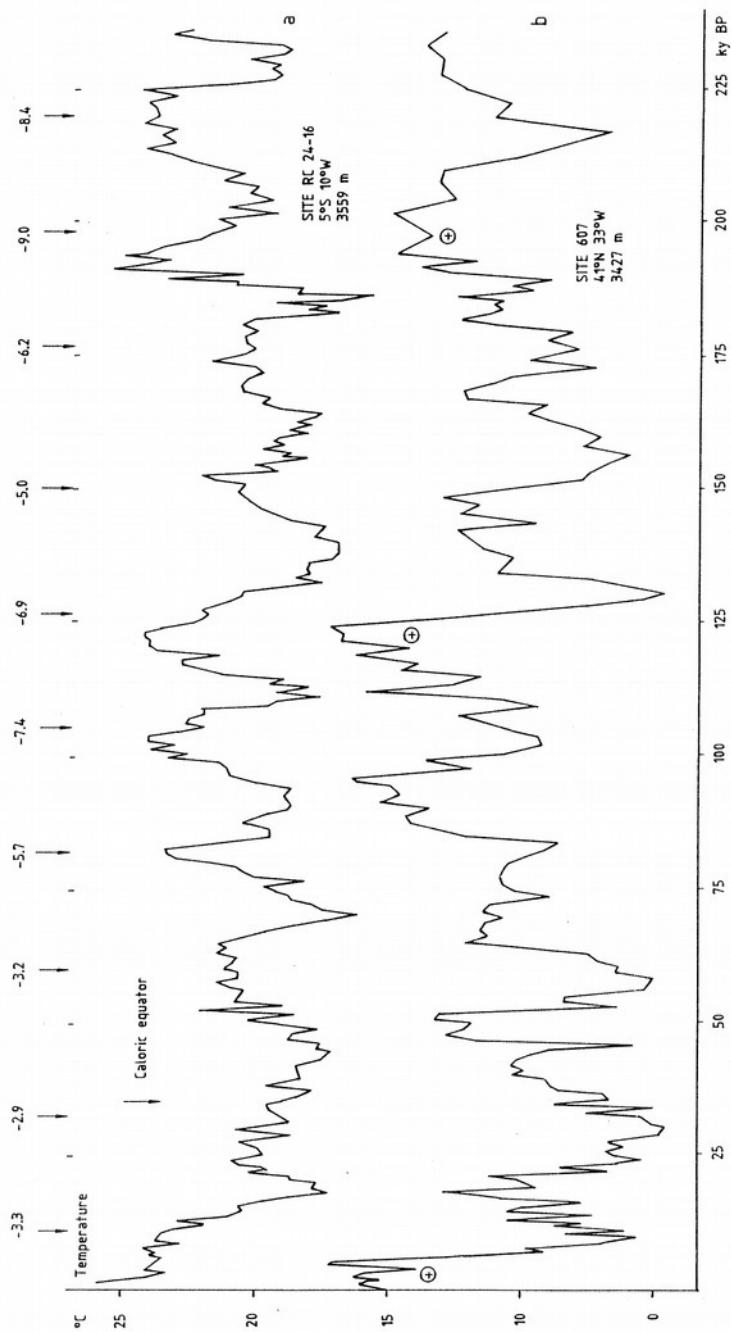


Fig. 15. SH and NH sea surface temperature responses.

cent of carbonate, usually produced in the ocean surface layers. Fig. 14b and 14c show a strong covariation with a small time delay between surface and bottom data. Organisms that live on organic remains, sinking to the bottom, will thus be influenced by the isotope situation in the surface layer, at least regarding the ^{13}C isotope and during periods when the amplitude of the variations are large. The relationships presented in Fig. 10 indicate that the statement also involves the ^{18}O isotope, but in a complex way. In figure 14d, the weight per cent of total organic carbon (TOC) is shown. Productivity, or rather bottom conservation of organic remains, seems to be dependant of local factors to a large extent while ^{18}O variations are not.

Peter deMenocal, et al. (1993), has performed an important investigation using data from DSDP site 663, (1°S , 12°W). This drill core contains much eolian sediment from the African continent, especially from boreal winter times. Spectral characteristics have been processed from 10 different proxy variables and it is obvious how some of them are controlled by processes originating in NH. Interestingly, the influence from insolation variations (23 ky period) is weakly developed in almost all of the proxy variables.

5.4. Observational evidence from North Atlantic Ocean

Site DSDP 607 will once again provide us with a range of data (Ruddiman, et al., 1989). The well known winter temperature variations from the equatorial site RC 24-16 (McIntyre, et al., 1989) is compared with winter temperature variations at site 607 (Fig. 15). These two curves define the glacial-interglacial problem to a large extent. The equatorial winter temperature variations do follow SH insolation variations. The site 607 winter temperature variations do not seem to follow either the NH or the SH solar insolation variations. The deviations from direct insolation forcing must involve interhemispheric effect transfer. It should be mentioned here that the time scales presented by the authors of papers are accepted, if not stated otherwise.

Going back in time at site 607, the Figs 16 and 17 illustrate variations in four different proxy variables, which are of importance when investigating the processes operating on time scales around glacial-interglacial periods. The different proxy values are often extracted from a single sample. The times given in the tables of Ruddiman (1989) is carefully reproduced in the figures to facilitate observations of time lags between the different proxy variables.

5.5. Other ocean derived observational evidence

Several proxy variables (time series) from the eastern Weddel sea at latitude 69°S , has been presented by Mackensen, et al. (1989) covering the last million years. The long term variations show very little of insolation variability but they do show all other common features in global marine ^{18}O variations.

The Arctic circulation system has shifted from a surface circulating pattern to a more direct flow towards Fram Straight during Pleistocene time, a conclusion based on ice-rafted debris from four cores in the Arctic Ocean (Bischof, et al., 1997). Salinity (and presumably ^{18}O oxygen) depends on fresh water input to the Arctic Ocean as does the circulation pattern in the Arctic Ocean according to Aagaard et al. (1989).

The ocean circulation is, in quantitative terms, investigated by McDonald et al. (1996) in an ambitious effort to include all major surface and deep sea

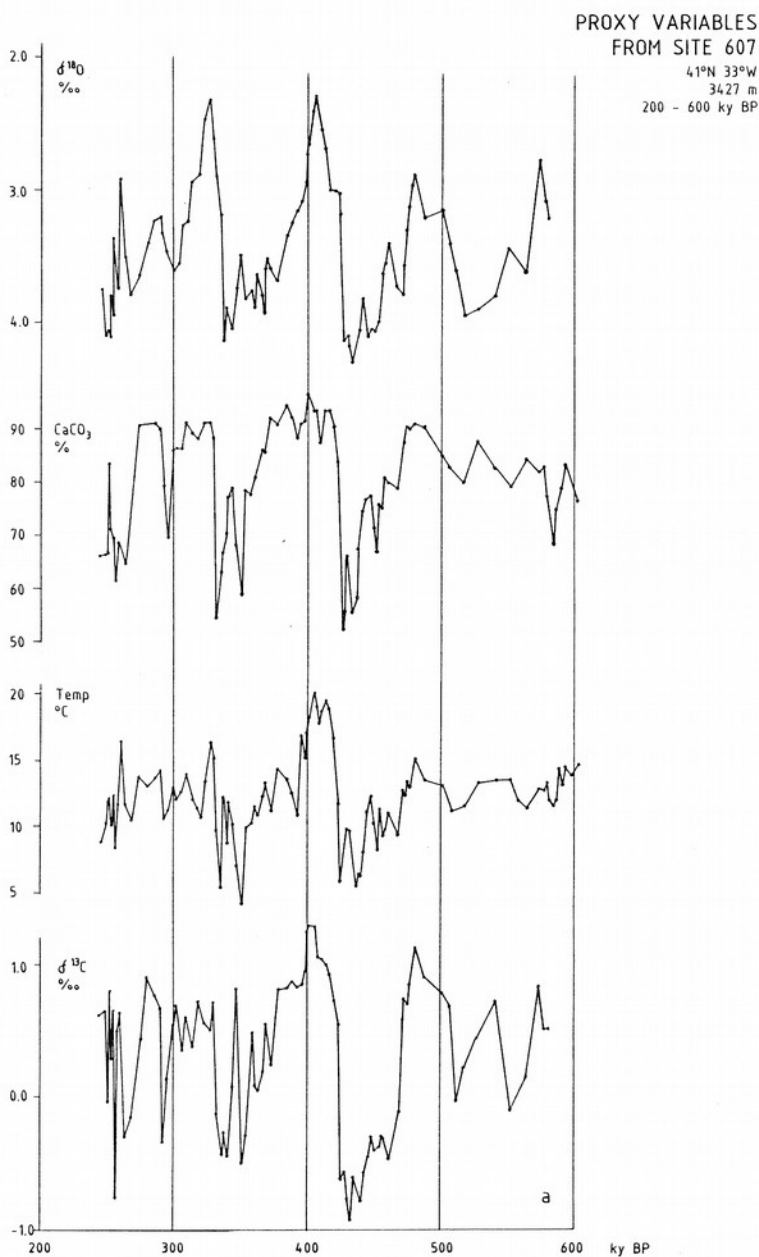


Fig. 16. Simultaneous proxy for the purpose of comparisons 200-600 ky BP.

PROXY VARIABLES
FROM SITE 607

41°N 33°W
3427 m
600 - 1000 ky BP

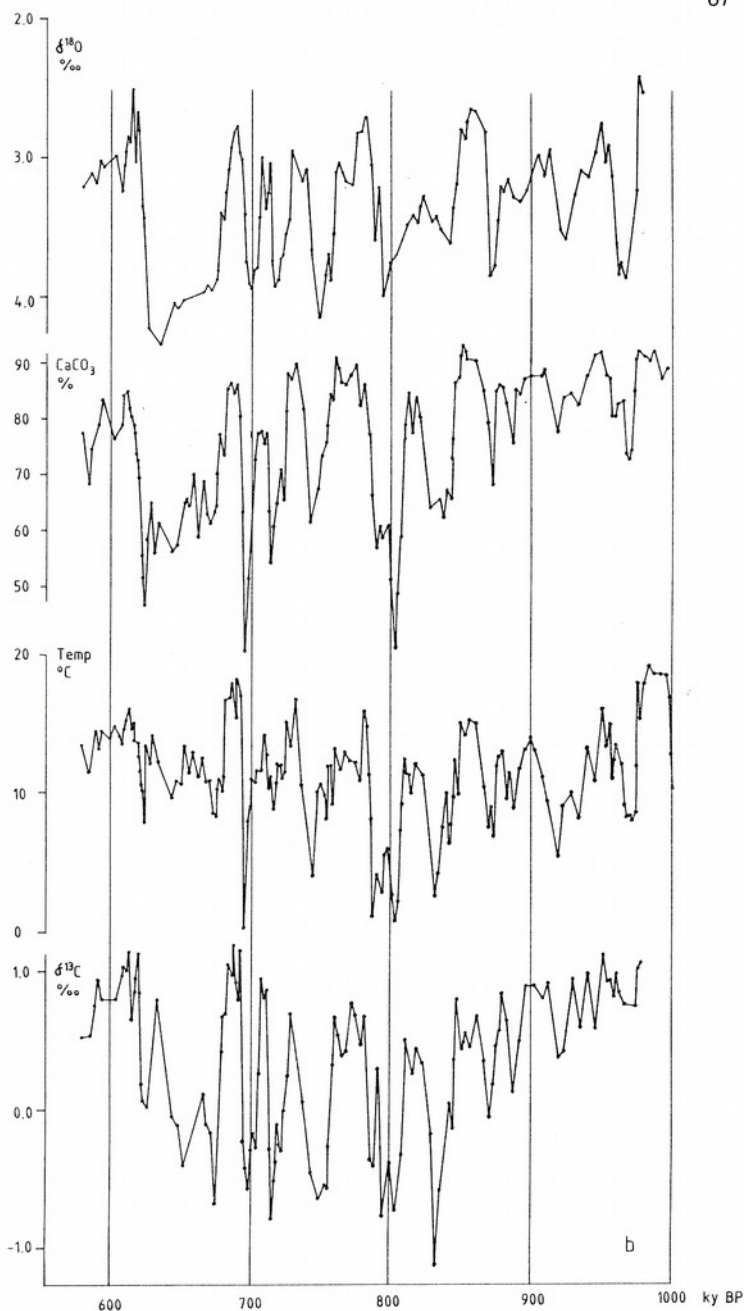


Fig. 17. Simultaneous proxy for the purpose of comparisons 650-1000 ky BP.

currents. The main route by warm water entering the Atlantic from the Pacific around Cape Agulhas is not explicitly pointed out as a large current by McDonald et al. This has been done by Gordon (1986), who by his paper confirms the energy transport that according to (II:2) has to occur. The warm water flow starts south of the Phillipine Islands and ends in the GIN sea. He does not, however consider the interhemispheric energy transport during glacial conditions. It is here assumed that the effect transfer will stay at a similar level, but that the sea surface temperature might be some degrees lower than during Holocene conditions. Most cooling of this current, during glacial periods, probably develops during the passing of South Africa in a flow opposite to the circumpolar current, and in northernmost Atlantic Ocean.

A thorough investigation of carbonate preservation in the Pacific Ocean have been performed by John Farrel and Warren Prell (1989, Fig. 4). They have used 1043 values of preserved CaCO_3 (%) from 16 cores to obtain a picture of time variations of the carbonate dissolution during the last 800,000 years. Two conclusions will be pointed out. The dissolution of CaCO_3 is least during glacial conditions and most developed during interglacial conditions. Secondly, they infer that the ocean water was more supersaturated with carbonate ions during glacial conditions, which lowered the lysocline, and increased preservation. The described phenomena is very important, since it is a direct evidence of carbon dioxide transfer to the oceans during glacials (windy conditions on a global scale). The variations in constant preservation (depth), clearly show an almost "clean" component of the glacial-interglacial cycles with a super cycle around 600 ky. Thirdly, their results prove the existence of an influential varying exchange of atmospheric carbon with the carbonate on the ocean bottom floor, pointing to potential influences in both carbon and oxygen isotope variations.

5.6. Land derived observational evidence

To clarify glacial-interglacial variations in a high latitude continental area, Colman et al. (1995) have extracted per cent biogenic silica in Lake Baikal as a proxy for climate change. They conclude that the found variations are in essence similar to global marine ^{18}O variations.

Another continental record is presented from Devils Hole, Nevada (Winograd et al., 1988; Winograd et al., 1992). The proxy variable is ^{18}O from calcite, precipitated on the walls of a ground water filled vein at a depth of 30 m. A continuous building up of calcite during 500,000 years has produced a 36 mm thick layer which has been sampled at intervals representing approximately 1800 years each. The authors claim that data from Devils Hole "yield an uninterrupted 500,000-year paleotemperature record that closely mimic all major features in the Vostok (Antarctica) paleotemperature and marine ^{18}O ice-volume records". This is an amazing statement since the biological, chemical and physical processes producing all three, above mentioned, ^{18}O records differ substantially from each other.

Some implications, derived from the Devils Hole data, do not favour the Milancovitch theory according to Winograd et al. (1988). This viewpoint seems to have been frustrating for Imbrie (1993) who probably, without saying it clearly, thinks that science should not deal with the Devil. Anyway, the data from Devils Hole is of great interest as a record from a continental area of

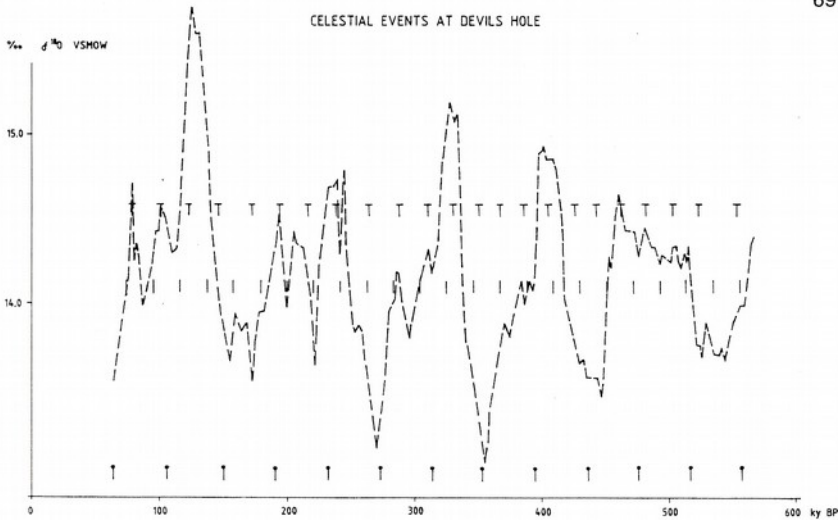


Fig. 18. Celestial events and data from Devils Hole (Great Basin, Nevada).

severe aridity (Fig. 18, modified from Winograd et al., 1992) covering a time period of more than half a million years. Observe that excess of ^{18}O is coupled to warm interglacial periods. The symbols in Fig. 18 are defined in the celestial time table of Fig. 11.

The ^{18}O data from Vostok (DeAngelis, 1987) strongly indicate colder conditions during minimum insolation (Fig. 5). The arrows indicate times when Earth is furthest away from the Sun and when this happens during austral winter, the temperature in Vostok reaches minimum values, which makes sense. An intriguing fact, is that ^{18}O data from inclosed air in the Vostok ice core (Jouzel et al., 1993), show variations that are almost identical to the curves in Fig. 12b and 12c, meaning that these variation are dominated by insolation variations in the southern hemisphere. This observation raises the question whether global atmospheric isotope variations are controlled by insolation variations to SH or not.

As a last example of land based climate observations, ice core data from Greenland might be appropriate (Dansgaard et al., 1993). The ^{18}O isotope time series cover a time span of 250 ky. Leaving the fast type variation just now, the base line in Fig. 19 shows variations of a slow type, which should be especially noticed.

5.7. Analysis of glacial-interglacial variations

The basic quantity that have to be identified in climate change is energy and its variations. These are so huge that there is no way they can hide if looked for. The second task is to find out what type of processes that can control the energy flows. These are not necessarily indicated by surface temperature variations, the variable that most proxy variables of biological origin measure.

The approach to identify the control functions will relate to the cyclic

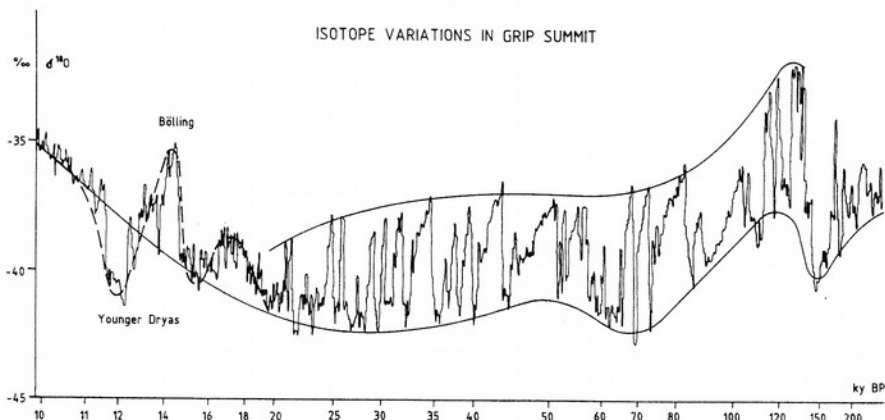


Fig. 19. Low to high frequency variations in GISP II isotope data.

behaviour induced by insolation in the first place and other celestial events in the second place. Relating events in time provides that used time scales are fairly accurate. These will always be the author's original ones unless otherwise is stated.

If energy flows can be related to either input of energy to the atmosphere and hydrosphere or the removal of energy as a function of hemisphere and of celestial events it might be possible to understand the forces behind the cycle, named the 100 ky cycle that has grown in intensity during the last million years.

5.7.1. Deductions from ocean surface temperature variations

A close look at Fig 15 will reveal that the temperature variations at site RC 24-16 respond quantitatively to MSCE. The highest peaks correspond to the highest insolation values with one possible exception, the situation existing today and since some thousand years ago.

The temperature variations at site 607 is not as regular as the ones at the equatorial site but it does show an anticorrelation with the equatorial curve except at three times, the last two interglacials and around 190 ky BP, marked by an incircled plus sign in Fig 15. This pattern strongly indicates that ocean surface temperature at site 607 does react to maxima in NH insolation but that this pattern sometimes is broken by extra energy input. The interpretation of these curves are that during certain periods massive interhemispheric overflow of warm intermediate ocean water occurs. This extra overflow might be concentrated to a certain season of the year. When this happens an interglacial is approaching if the overflow continue long enough. The effect transfer is probably diminishing during a long period spanning several caloric equator periods. This interpretation is supported by the base line in Fig. 19. As can be seen the minimum temperature at Summit, Greenland, sunk during a period of 50 ky after the Eemian interglacial. The interpretation is that excess energy in the North Atlantic kept up the minimum temperature at Summit for a long time period.

Site RC 24-16 is a location, where extreme mixing of ocean waters occurs, which is confirmed by Fig. 13. The in phase variations, denoted by an f, during both summers and winters are no artifacts. The seasonal difference stays intact but other factors make the temperature vary around 3°C in periods of some thousand years. Another event (e), bear witness of massive ocean water energy exchange and it is showing up at all three locations. Insolation variations are not seen at site V 25-59 since it is located in the middle of the warm water current that constantly carries energy from SH to NH. Event e interrupted the commonly so smooth ocean surface temperature at the site V 25-59, especially during winter. The natural explanation is that massive extra warm water flux to NH was replaced by cold water from NH of such a magnitude that it shows up along the whole equatorial Atlantic Ocean. *The melting of NH glacial ice is fueled by SH ocean sensible heat in the first place.* This extra spilling over of ocean energy is probably an ocean equivalent to NISE (II:5). The reason why and when "extra" energy exchange occur should be clarified if possible.

5.7.2. Atmospheric infrared emission

From Fig12 it is clear that the SH ocean energy reservoir reacts on insolation variations and from Fig 5 it is clear that SH polar temperature reacts on tilt and distance from the sun.

An indirect evidence, telling that infrared emission from NH is controlling much of climate change, is manifested in the work done by deMenocal et al. (1993) mentioned above. The core site registers in the first place eolian components during winter time wind regims. This means that the governing mechanism producing the winds are NH mobile polar highs (II:3). The main frequencies found by deMenocal et al. are 41, 69 and 100 ky. The 100 ky period in ^{18}O (from *Globigeroides ruber*) is one of the most dominant ever recorded. The 69 ky period dominates carbonate and total mass accumulations rates, while the 41 ky period dominates per cent terrigenous material. Both the 41 and the 100 ky periods dominate terrigenous mass accumulation rates. The NH wind system produces predominantly eolian variations at 41 and 100 ky periods. The authors attribute the 41 and 100 ky periodicities to "high latitude" forcing.

The Vostok curves in Fig. 5 show a mixture of 41 ky and 100 ky signals. If, which is very reasonable, the eolian products in the equatorial Atlantic Ocean, west of Africa, are produced by the action of MPH:s, the 100 ky signal has its origin in NH atmospheric conditions. Furthermore MPH:s are produced by infrared emission into space, thus the 100 ky period should originate from a process that dominates infrared emission from NH. Such conditions are favoured by maximum tilt of Earth's axis during NH winters when Earth is at an aphelium position. The tilt period is 41 ky and the distance from Earth (eccentricity) is said to vary in 100 ky cycles. The "beat" frequency between these cycles are is 69 ky. The dominant infrared radiation in NH might be an effect of the larger land areas in NH favouring the infrared emission or it might be controlled by tidal effects of unknown origin. Whatever, It is here argued that the 100 ky signal found in SH oceans and in Antarctica are secondary in a manner equivalent to how NH global longitudinal atmospheric momentum dominates the global atmospheric momentum today.

5.7.3. The 100 ky signal in ocean carbonate

The existence of the 100 ky signal in carbonate ^{13}C and ^{18}O (Fig. 16 and 17) is proposed to mainly be a secondary effect of atmospheric/ocean interaction under wind stress and added to that ^{18}O variations caused by global ice accumulation. The scenario implies that increased infrared emission from NH cause strong winds by intense production of MPH:s that move south to southwestwards. The stronger surface winds force more carbon dioxide into the water, change the biological ocean surface life conditions and fractionate both carbon and oxygen until a new balance situation is reached. Since the surface water in the Gulf Stream stays in a surface position for a long time, this water can, and will be marked by an isotope imprint that will spread to the other oceans when the Atlantic surface water finally cools and sinks. This will produce a "global" signal since all oceans will be marked by the variations. This should also explain why the lysocline show a fairly "clean" 100 ky variation (Farrel, et al. 1989).

The ^{18}O variations in *G. sacculifer* and 3-25 micron grain size (mainly coccoliths) from one single Caribbean drill core P6304-4 (Anderson et al., 1981), is shown in Fig. 20a and 20b. The fine fraction curve has about double the amplitude as the other. The authors suggest that selective dissolution or deep calcification during interglacials reduced the amplitude of *G. sacculifer*. The interpretation favoured here is another. The amplitude difference probably depends on complicated biological factors in combination with inorganic chemical surroundings at a specific place. These conditions are probably surface wind strength dependant, in a way which is here considered to be incomprehensible. Whatever the cause is, both of them can not be interpreted in a linear way to show accumulated global ice volume. The curve emanating from the coccoliths, resembles the SPECMAP stacked ^{18}O curve but the amplitude is too large.

Fig. 20c and 20d are modified from Clemens et al. (1991). Assume that ETP in SH have a profound effect on ^{18}O in foraminifera and that the amplitudes of the normalized curves are fair approximations of the correct amplitude relationship. By subtracting the negation of curve in Fig. 20d from 20c the curve in 20e is achieved. The curves are adjusted in vertical position so that the difference between them is zero about 8 ky BP. There is a theoretical way to argue that the difference should be a proxy value of accumulated ice volume relative Holocene ice volume. It is interesting that the curve in figure 20e is so smooth and that the zero line becomes straight in such long intervals during interglacial conditions. Future research will reveal if this simple "elimination of incomprehensible subsystems by subtraction" turned out as a good proxy or not.

A support for the proposal above might come from Clemens et al. (Fig. 6, 1990). They show the lithogenic (eolian) mass accumulation rate in RC 27-61 (17°N, 60°E) in the Arabian Sea during 350 ky. The mass accumulation rate at this location can be argued to be a proxy for NH absolute wind speed and thus a proxy for global ice production. The curve they show (negation of) looks very much like the one in figure 20e.

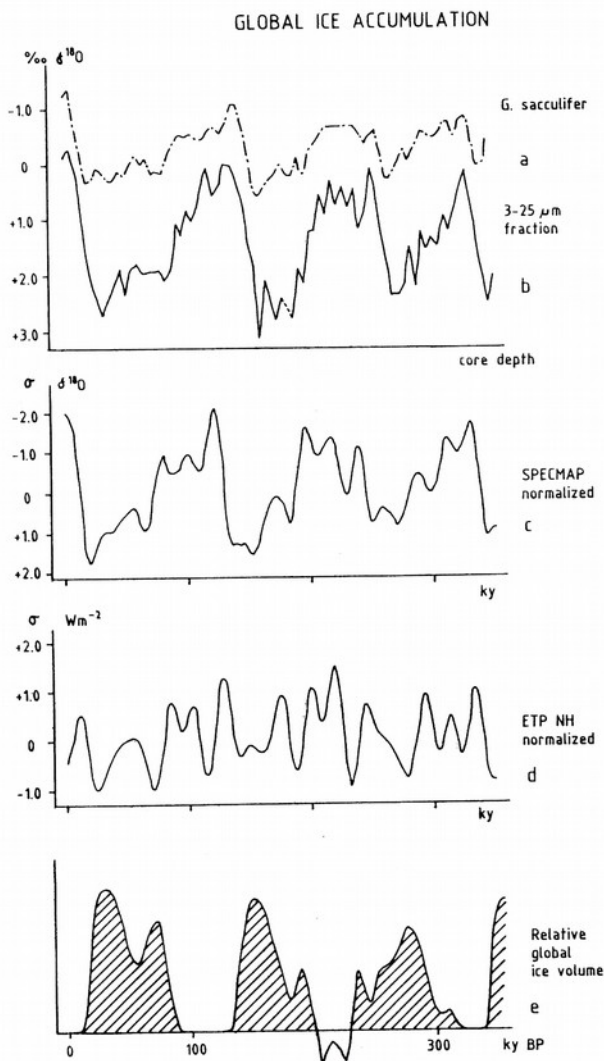


Fig. 20. Incomprehensible systems, global ice volume and ^{18}O isotope variations.

5.7.4. The "case" from Devils Hole

The oxygen isotope time series from Devils Hole will be analysed using the following assumptions:

1. The time scale, based on uranium dating is accurate and probably better than the authors themselves believe.
2. The ^{18}O variations are interpreted as showing atmospheric influences depending on interaction between the water surface layer and the atmosphere.
3. The water-atmospheric interface is surface wind dependant regarding the carbon dioxide isotope balance.

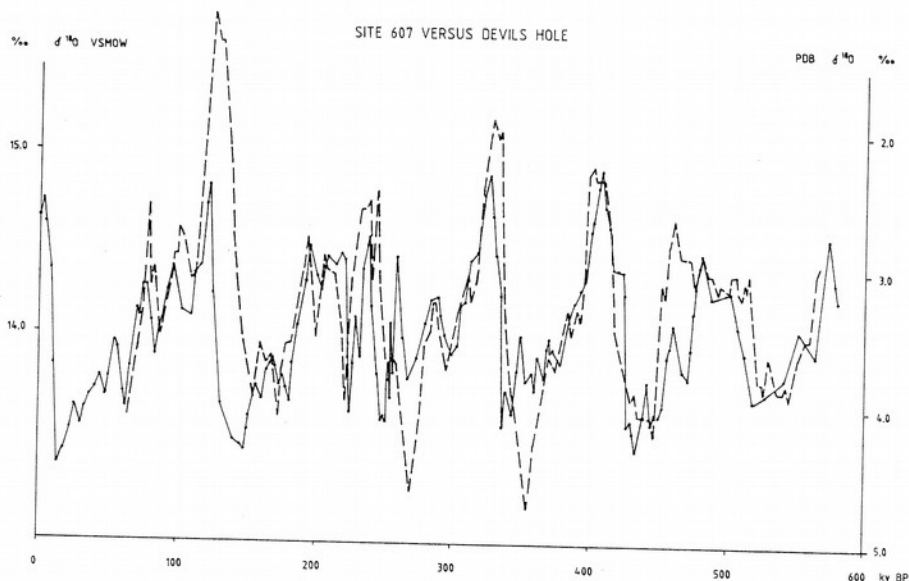


Fig. 21. Comparison of marine and continental ^{18}O data variations.

Based on these assumptions, the following observations can be made by comparing oxygen isotope variations with celestial events. Looking at Fig. 18 and Fig. 11, the following statements are motivated:

(1) The three lowest peaks in the curve (Fig. 18) are coinciding with maximum tilt and summer in SH near the aphelium position of Earth. Added to that, the youngest negative peak probably also coincide with the same conditions. The interpretation of these negative peaks are cold atmospheric (winter in NH when Earth is far from the sun) conditions and high surface wind speeds.

(2) The positive peaks in the curve are usually coinciding with maximum insolation in the SH (maxima of caloric equator) after a delay of 4 ky. The caloric equator symbols have been shifted this time interval in Fig. 18. The coinciding events are interpreted as warm and calm conditions in NH when NISE (II:5) is active. The time shift is interpreted as the time for reaching a new biological, chemical and physical balance after changing SH insolation.

(3) At three consecutive occasions 200-240 ky BP, when Earth was close to the Sun in a perihelium position and when there was summer in SH, there are negative spikes in the record. This is interpreted as showing influence from the orbital position affecting the switching of NICE. The off periods are short compared to other variations in the curve.

The time correlated events mentioned above do vary a lot in magnitude. The greatest reason, seems to be the influence from interhemispheric energy exchange in the oceans, which dominates the interglacial conditions and thus also influence the atmospheric temperature, isotope balance and surface wind conditions. It should be noted that the process of turning on and off NISE and interhemispheric ocean energy exchange, still remains unexplained.

The ^{18}O variations from site 607 is compared with data from Devils Hole in Fig 21. It should be noticed that here that both planktonic and benthic foraminifera isotope variations, by the author, are interpreted as mainly indicating variation in ocean surface conditions. The correlation between marine ^{18}O and ^{18}O at Devils Hole (Fig. 21), is evident as is accepted by Imbrie et al. (1993) but there are deviations. The strongest negative peaks in the curves deviate considerably. The main reason might be that at Devils Hole wind control is the dominating process, but for the oceanic curve wind control and ice volume are both influential. The positive peaks also deviate, especially around the Eemian interglacial. The basic insight is that the turning on and off of NICE and the massive type of ocean effect transfer, do not have to coincide. If this interpretation is correct, the NICE process started just after the maximum tilt 150 ky BP and led the ocean energy transfer by 12ky. Another interpretation is a mismatch in time scales, an idea which is not favoured here in the first place.

The variations around 200 ky BP are interesting. The dips close to 220 ky BP in both curves are probably identical, planetary position dependant and wind induced. The phase lag between the curves around 245 ky BP is interesting and might be a consequence of different processes operating in the atmosphere and the oceans. The dips in the curves at 270 ky BP seem to be identical in time and wind induced. There are many more points to be made but the mentioned coincidences hopefully support the assumption initially made above.

5.8. Summary and conclusions of glacial-interglacial climate change

Cyclicities around 100 ky have been registered in sediments regardless of the surface temperature on Earth and everywhere on Earth. The existence and amplitude of the 100 ky cycle that is intimately tied to the development of severe glacial conditions in NH might not be the same period as that registered in Cretaceous sediments. The glacial candidate seem to have a period centered around 100 ky while the warm climate one might be 111 ky. The latter might register the sidereal period of the perihelium position while the 100 ky truly is a consequence of periodically increased infrared emission from Earth.

It is here argued that the receiving of energy into the energy reservoirs of Earth is dominated by insolation to SH. In both hemispheres there are an infrared emission locked to the tilt frequency of 41 ky. This emission is naturally phase shifted in the hemispheres. The amplitude of the 41 ky emission is suggested to be stronger in NH than in SH. This statement is based on the distribution of land and oceans and the possibility for SH ocean energy to "counteract" MPH:s moving northward from the Antarctic continent.

The infrared emission is thus dominated by NH effect output. This is probably true both during glacial and interglacial conditions. The excess output of energy from NH is compensated by three basic mechanisms. These are (1) "Constant" ocean interhemispheric surface flow during both glacials and interglacials, (2) periodic massive overturn of intermediate half warm Atlantic Ocean water from SH to NH which is replaced by cooler NH Atlantic Ocean water. This process should exist also in the other oceans, but in that case, to a much smaller extent. The ocean water overturning is the basic process for melting NH glaciers, built up during long times. (3) NISE constitutes a fast

varying process, transferring SH atmospheric sensible heat to NH during certain time periods. Coinciding ocean hemispheric interchange and the turning on of NICE do create an interglacial but the main energy source is coming from the ocean energy received in SH. After a massive ocean turnover transfer of energy from SH to NH the SH oceans have to build up the energy storage again. The possibility to do so, is to a large extent depending on the infrared emission from NH, which is controlled by eccentricity variations and/or other factors of unknown origin.

This infrared emission from NH varies at a frequency close to 100 ky. The NH infrared emission dominates the energy output from Earth and the intensity of the 100 ky cycle has been dominating during the last 800 ky. This periodicity is then transferred, via wind dependance, to all living organisms on Earth and will show up in all organic matter, especially living in ocean surface layers but also on the ocean floor.

The 100 ky periodicity is probably controlled by celestial factors that dominantly affect NH or dominantly affect infrared emission from land surfaces of Earth. A condition for this effect to create a substantial ice volume in NH is that the deep ocean temperature is close to 0°C. Earth's oceans have been approaching this condition during a long time. The closing ridge at Panama and the elevation of the Tibetan Plateau probably induced an extra ocean cooling about 2.5 million years ago increasing the climate sensitivity to changes in NH infrared emission. About 800 ky BP a last cooling episode occurred, meaning the full development of a global climate system, that reacts strongly on the 100 ky cyclicity in infrared emission.

5.9. Results related to the preferred model

The glacial-interglacial changes partially depend on a struggle between insolation variations and variations in infrared emission from Earth. The assumed fact, that energy storage on Earth is dominated by ocean sensible heat in SH is complemented by the statement that infrared emission variations in NH dominate global infrared emission.

The new knowledge concerns the massive, intermittent transfer of ocean energy from SH Atlantic Ocean to NH Atlantic Ocean during certain periods as a "complement" to the nearly constant ocean surface water energy transfer. The control of this extra transfer is suggested to be triggered by celestial events, probably working via the HDF process in a way similar to the turning on and turning off of NICE. But before strong ocean interhemispheric energy transfer can occur, the ocean water in NH have to be cooled to a considerable degree. This is supposed to be driven by increased surface wind speeds in NH, thus increasing the cold water production in the GIN sea and the volume of stored cold bottom waters in NH.

The increase in NH wind speed is strongly suggested to depend on celestial factors, where the distance from Earth during aphelium (eccentricity dependance) during NH winter might be responsible for the 100 ky cyclicity. This strong dependance is possible since the two hemispheres don't react equally regarding infrared emission for reasons suggested in the text above.

The reasoning made, do not prove a control from unknown "tidal effects" but the coincidences in figure 18 strongly indicate a non Milancowitch influence.

The prime candidate is a physical process, primarily influencing the infrared emission. The deductions made implicate that the AIS in figure 4 might be as important as was originally suspected. The scenario expressed above, also focus the attention on the feed back from AIS to the atmospheric circulation system and further on to the ocean circulation system. If these proposed causes and effects are correct, then the glacial-interglacial climate change is primarily run by:

1. NH variations in infrared emission governed by celestial factors (eccentricity) variations alone or in combination with unknown factors.
2. The building up of sensible heat in the SH oceans.
3. The building up of cold water masses in NH.
4. Occasional releases of the SH ocean energy storage into NH by HDF in combination with unknown factors.
5. The turning on and off of NICE by unknown factors.

The unknown factors can originate from outside Earth and will then be called "tidal effects". There are still reasons to keep the model in Fig. 4 as proposed.

6. Holocene-last glacial climate variations

6.1. The relativity of climate change

Much has been written about Holocene climate change especially during the last 150 years. Still, these climate changes have to be like taking a deep breath and blow the air out as hard as possible and then compare it with winds in a storm. The reason saying so, is that the climate on Earth during glacials were of such a nature that it is hard for us to comprehend its violence, because we do not have a reference frame in human experiences. There is a lot to learn in studying modern climate variations, but it has to be connected to the whole climate picture.

As an example, have another look at figure 19. The oxygen isotope values, a proxy for temperature during the Holocene, are very close to -35‰ during the last 10 ky (Dansgaard et al., 1993). The Summit temperatures in figure 19 indicate a glacial-interglacial shift of 10°C or more. This perspective should be kept in mind, when changes during modern times are investigated.

6.2. Some modern examples of climate change

A wonderful example of scientific knowledge is contained in a little article (Peterson et al., 1995) which is named "Evaporation is losing its strength", an article that almost for sure soon will fall into oblivion. During more than 50 years, the rate of evaporation has been measured in the simplest possible way, by observing daily evaporation from an open pan. This has been going on in Eastern US, Western US, Europe, Middle Asia and Siberia. All places except in Asia show a statistically significant trend towards lower evaporation. These time series constitute heavy observational evidence that cannot be denied. They ought to be interpreted as a decrease in the NH mean surface wind strength in the first place, and as an indicator of warmer climate in the second place. The result is a strong indication of wind controlled climate, even if the changes are of a minor importance.

Every year 3.2 million ton of tuna fish are harvested, mainly in the western Pacific. The Southern Oscillation Index (SOI) might now be exchanged by the Longitudinal Tuna Index (LTI), since it has been showed that maximum tuna

fish catch follows the eastward advance of the pool of warm Pacific Ocean water, that is coupled to ENSO events (Lehodey et al., 1997). Even if SOI will not be exchanged, the information should lead to second thoughts. This is an example of how sensitive the planktonic fauna is, and how strongly these mild climate phenomena interfere with the average pattern of life in an ocean area. When measuring isotope changes or per cent abundance of species, the true interpretations might be in terms of wind strenghts or in terms of ocean surface recirculation intensity or changes in ocean surface current systems.

To continue with fish harvesting, it does change in the Atlantic Ocean too. When facing times of low harvests of cod (10-20% of normal) this was thought of as an anthropogenic effect, caused by overfishing. By investigating a more than 300 years old time series regarding cod harvests, two prominent frequencies could be secured, relating to periods of 10.8 and 18.4 years. These are interpreted as induced by the sunspot cycle and the nodal tide (Moon-Earth-Sun cycle). The article is named "Cod stock-recruitment problems, the nodal tide, and sunspot cycles", Wyatt et al. (1992).

These data have to be accepted as representing existing phenomena in nature and cannot be disregarded. It took a long time for the author to find a plausible cause to the variations in the cod stock. Anomalous sea surface temperatures down to 1.5°C have been measured outside Ireland. An article mentioned that cod fries do not survive in waters below 2°C. The conclusions reached are (1), occasionally very cold water masses invade the North Sea over the areas where the cod fries grow up, and (2) the motions of these water masses are initiated intermittently by tidal effects. The claimed variations are another example of how sensible life forms are to changes in the ocean circulation system.

In an impressive work examining flow variations in the Nile River, Currie (1995), shows that also here the sunspot cycle and the nodal tide cycle, dominate in a time domain spanning periods of 8-30 years. Currie has very interesting viewpoints on the use of different scientific techniques and the process of gaining knowledge, which could be titled "use and misuse of scientific tools". He has showed the existence of deterministic signals in climate data over and over again, and still, the scientific community seems to prefer a world of chaos, where the wings of a bird in New York might induce a storm over the Atlantic Ocean, of course without showing supporting evidence from nature.

A periodicity of 18.6 years is found in the drought occurrence in the US (Laird et al. 1996). The main cycle is claimed to have been especially strong during certain periods, such as 200-370, 700-850 and 1000-1200 AD. Once again the same period shows up. This is no coincidence. There is a multitude of references. An overview is given in "Selected bibliography of short-term cycles", by John E. Sanders and Rhodes W. Fairbridge (1995). They have selected 450 articles they considered worth reading. Many of them directly point to the influence of tidal effects on the climate system of Earth.

6.3. The energy source of quasi-cyclic circulation variations

Climate cycles seem to exist in all frequency ranges. If they coincide with known celestial frequencies there are obvious reasons to investigate influences from celestial objects and parameters involved. For cycles of 2-3000 years

there are few such obvious correlations to investigate, but climate variations do exist. To find an agent causing them within the terrestrial systems is not easy. In that case it has to be some type of energy oscillation, triggered by some unknown factor or by chance. Believing in an extraterrestrial triggering system, it could act in two ways, as a clean trigger effect releasing an earthbound energy reservoir or as a trigger combined with energy transfer that makes the oscillations go on despite obvious friction losses in the climate system of Earth.

These arguments could as well be applied to the generation of sunspots. Where is the triggering mechanism located, and if found, is it only a triggering effect or does it also supply or withdraw energy from the system it belongs to? Looking at the energy reservoirs on Earth, only sensible heat of the oceans can theoretically start oscillating for a sustained period without constant refill of energy. The reason being that atmospheric friction losses would stop all winds after a couple of weeks, if energy supplies were cut off. A sustained atmospheric oscillation would thus need energy support from the oceans or from an extraterrestrial source apart from the Sun, if proven it was not fueled by solar radiation.

Of special interest is the quasi-biennial oscillation (QBO) that is an atmospheric oscillation that can hardly get energy from the oceans, and whose period does not coincide with any insolation variation or its harmonics. QBO is an equatorial air stream at a height of 15-35 km. This oscillation is a good candidate to be controlled by an extraterrestrial influence or what we here call tidal effect. It is generally known that the length of the day (LOD) covary seasonally with the global longitudinal atmospheric momentum which is dominated by the NH atmospheric momentum since it is the larger one. (ref) This fact is here interpreted as an effect associated with seasonal or shorter period latitudinal mass redistribution, mainly in NH associated with the production of MPH:s. The presented correlation is high, indicating that factors disturbing the relationships are of a small magnitude. The seasonal variations in LOD are thus induced mainly by variations in the atmospheric circulation, for periods less than a year and a half.

At frequencies with periods of 1.5-10 years, Chao (1989) has claimed that variations in LOD can be described as a sum (linear combination) of QBO and ENSO variations. Furthermore, he states that these two variables are uncorrelated, that is, they probably have different causes. ENSO is responsible for around 2/3 of the variations in LOD within this frequency range and the rest is associated with the QBO. An interpretation can be: (1) QBO is associated with mass redistribution in the atmosphere with a quasiperiod around 27 months and, (2) ENSO is caused by mass redistribution in the oceans causing a more variable quasicyclcity. Changes in terrestrial circulation systems thus make Earth shaky. We are back to the question, what causes the atmosphere and ocean water to move, internal factors of terrestrial origin or tidal effects?

Both the importance of ocean circulation pattern for planktonic life forms and the influence of tidal effects, are shown in the article "Signals in the interannual variations of zooplankton biomass in the Gulf of Alaska". Hameed, et al. (1995) claim the detection of, by the use of signal processing over a 24 year period, the influence of polar tide (around 14 months) and the QBO in the Alaskan waters. The authors describe the variations in biomass as "due to a poorly understood interaction between primary and secondary productivity,

nutrients and physical factors", a type of system which here has been called incomprehensible. The QBO frequency found in the water circulation is a strong indication that QBO is caused by purely tidal effects, since the variations are both found in the atmosphere, above the equatorial troposphere and in Alaskan water circulation system together with another effect, that is unquestionably of tidal origin. This points to a tidal effect working on both the atmosphere and the hydrosphere. Furthermore, the frequency of this tidal effects is such (27 months) that the existence and influence of planetary tidal effects should be seriously considered (Mörner, 1993b, 1996).

6.4. Physical processes proposed to control energy redistribution

Two processes will here be claimed to have the capacity to redistribute energy in the terrestrial energy reservoirs.

- (1) Redistribution in the atmosphere via subsidence energy (II:6).
- (2) Redistribution of energy via horizontal density forcing (II:4) both in the atmosphere and the oceans.

(3) The processes 1 and 2 in cooperation, which might be the usual condition. Redistribution of energy in the oceans via a subsidence effect is not excluded, observational evidence is just lacking.

6.5. Triggering mechanisms for energy redistribution

In some cases it is obvious that the subsidence effect is primarily caused by HDF. So is the situation in the Hadley circulation system. Air uplifted at ITCZ has to move somewhere. It moves away from ITCZ and forms a high pressure zone about 30° away, both over oceans and continents.

The triggering mechanism for NISE is not that obvious. In this case half the globe (NH) can be considered as an atmospheric high pressure cell. What causes determine if and when it should act like that? Enormous pools of cold water seem to be built up in the North Atlantic. When and why do they start moving southwards? The answers are left to future suggestions and research. Since space is the dominant energy sink, the factors controlling infrared emission into space are again in the focus of interest. Here the crucial question is: can tidal effects directly control terrestrial infrared emission or is that solely dependent on the distance from the sun. Up to now there is no direct evidence of what type of process or processes are causing the intermittent releases of stored energy in the climate system of Earth.

6.6. Observational evidence

Combining the reasoning above with Fig. 16 (modified from Dansgaard et al., 1993) is leading to the following scenario:

Massive intermittent ocean energy transfer to NH before the Eemian interglacial made the NH glaciers to melt rapidly by the action of warm ocean water in the North Atlantic Ocean. This intermittent energy transfer gradually decreased during 50 ky and then stayed at a cool level for 50 ky. During these 100 ky, the NH atmosphere occasionally received energy from SH when NISE was in operation. Both these processes seem to be controlled by a switching on and switching off mechanism. Around 20 ky BP, SH Atlantic Ocean began to transfer warm intermediate water to NH again, judged on the basis that slow variations in isotope values are evident. NISE added energy on top of ocean

bound energy. The variations of Bölling-Younger Dryas, might be the response to a strong warm ocean water pulse from SH Atlantic Ocean, followed by a strong infrared emission in NH, with the NISE process operating intermittently with a low amplitude during the warm period. The pulse defined by the Bölling-Younger Dryas, might have been triggered by the position of Earth at its perihelium position with maximum insolation during SH winter 11,000 years ago. The prominent variations in both atmospheric and ocean energy transfer to NH seem to have ended in a state of peace at the beginning of the Holocene and since then NISE has been operating without severe interruption. The Little Ice Age might have been a small indication that NISE is close to changing its state of operation. If it does, the Little Ice Age will just seem like a small incident in comparison.

The interpretations made above were based on a proxy temperature at high elevation in Greenland. Fig. 15 actually shows proxy values of the Atlantic Ocean winter surface water temperature at site 607. It is governed by NH solar insolation except at the absolutely most massive transfers of warm water from SH which actually have caused the terminations of glacials.

Fig. 13 reminds us of the tendency for quasi-periods to show up. At the equator, in the middle of the Atlantic Ocean, the mixing of SH warm water and NH cold water influence both the sea surface winter and summer temperatures which are changing up to 3°C in quasi-cycles of 2-5 ky. This is truly amazing. The phenomena extended across the whole Atlantic but are best developed in the central equatorial Atlantic Ocean. These variations are interpreted as the response to forced pulses of cold water moving southwards across the equator, driven by HDF and getting replaced by warmer SH water.

Compared to energy flow variations during glacial conditions, variations during the Holocene are like a whisper. Still, a very strong case for the existence of the subsidence effect during Holocene conditions was shown by Jelbring, (1997). In this work, century scaled temperature variations (amplitude 1.5°C) in middle Europe is negatively correlated with temperature in Northern Africa. NH warming during the last 150 years, often used as an evidence of global warming, can be compared with a cooling of a similar magnitude in Northern Africa during the same time interval. Here, regional energy transfer caused by variations in the subsidence effect is proposed.

6.7. Tidal effects in high frequency climate change

The literature covering climate change during the last millenium and the Holocene is enormous. Only some topics have here, been illuminated as by a spotlight. One such topic is the existence of tidal effects during the last millenium. A serious answer might still be similar to the one Herman and Golberg stated (1979). "This book also examines some experimental concepts useful for investigating physical links between solar variability and meteorological responses. The rationale for this objective is that, despite the vast literature supporting a probable connection between the two phenomena, there is considerable disbelief for such a connection. This disbelief seems to be based principally on the fact that no plausible physical mechanisms have been identified to explain how the relatively minor fluctuations in solar energy output can influence or drive the vastly more energetic meteorological processes. If

linking mechanisms can be identified, the subject of Sun-weather relationships will be on much firmer ground, and improved predictions of climatic trends and weather changes may in fact become possible." This was written 19 years ago. The arguments are still valid.

It should also be stated, that if tidal effects are prominent in controlling climate change, there will probably be different types of tidal effects, and this might be one reason why it is so hard to identify them and specify how they act.

6.8. The results related to the proposed model

Since high frequency climate variations can be shown to be tied to Sun-Moon-Earth positions and to the solar cycles, it would be proper to have an input named Tidal Effects in the model. The reasoning concerning the ultimate cause for ENSO and QBO variations points to relocations of atmospheric mass and ocean mass in nonseasonal periods, thus changing the circulation patterns. Tidal effects causing infrared emission variations, via influence on ASI, could be a direct or indirect forcing mechanism, although this proposal is very speculative. The importance of the ocean energy reservoir is very evident, both for generating large variations in sea surface temperatures (5 ky scale) and also for producing the massive transfer of energy to NH, that is melting NH ice-sheets at the onset of the deglaciation period. The forces causing these processes are waiting for a proper identification. One approach would be to propose that the turning on was induced by tidal effects while the turning off was induced by the drainage of energy from the used energy storage, whether regional or hemispherical or global.

What we have found out still fit the model even if it would have been nice if the number of questionmarks could have been diminished somewhat more. Anyway, it seems as the proposed model still can serve as a reference frame when continuing the analysis.

Part IV

Summary, conclusions and statements

1. Summary

In the search for knowledge, trying to unravel the mysteries of climate change, many tasks have been performed. They include theoretical viewpoints on scientific knowledge, questioning of the validity of proxy variables, proposals of basic processes in climate subsystems and a suggestion of tidal effects as a control of terrestrial redistribution of energy. The proposed global flow model has served its purpose to identify several main subsystems and processes and as well as being a reference when discussing and comparing observational evidences with model functions.

The possibility to prove a hypothesis in a true scientific way is limited because nature and its subsystems constitute an incomprehensible type of system. Furthermore, most data have to be gained indirectly by the use of organic remains, that themselves introduce inaccuracies in proxy variables.

For these reasons, knowledge concerning nature and its subsystems has to be built on chains of circumstantial evidence, mostly of an observational type, that together finally exclude all hypothesis but one. This way of working is similar to the one used in law, where this type of problems are well known. The consequence of this reasoning will be that what is here called a conclusion or a statement is not proven in a strict scientific sense, and it might not be possible to ever do so. The only way to reach a verdict beyond reasonable doubt, is by the testing of other scientists using independent methods.

The ^{18}O isotope has been questioned as a good proxy variable for global ice volume by showing its coupling to the interaction with biological, chemical and physical processes of incomprehensible type. The interpretation of data from benthonic foraminifera has been inferred to mainly reflect life conditions in the ocean surface layer with a short time delay relating to planktonic data.

Selected important processes concern the terrestrial surface temperature as a function of atmospheric mass, terrestrial redistribution of energy by the subsidence effect, the motion of terrestrial fluids induced by horizontal density forcing and the induction of terrestrial infrared emission variations by an incomprehensible process affecting the atmospheric-space interphase.

Tidal effects have been proposed to control the climate processes by identifiable influences from the Moon and the Sun but also by unidentified types of interactions.

2. Conclusions and statements

With the restrictions mentioned regarding a strict proof of hypothesis dealing with climate change, the concept conclusion will here be used in the sense that it mainly relies on other scientists data, usually from independent sources and will thus have a status of validity based on this fact.

Statements will be used in the sense that they mainly, at least to the knowledge of the author, are based on arguments and reasoning that are not

included in the prevailing scientific picture of climate systems, and have not been claimed by other scientists. Thus, statements are more sensible to personal mistakes, misunderstanding, faulty deductions to mention some sources of errors. Statements need confirmation by independent scientists before being generally accepted.

Some conclusions concern secondary issues of climate change:

(1) The ^{18}O carbonate isotope as a proxy for global ice volume is ambiguous because of incomprehensible processes relating to biological, chemical and physical interactions, setting up new global balances between isotopes during different climate regimes, and also during shorter periods such as Younger Dryas.

(2) The similarity between planktonic and benthic isotope time series is primarily due to the rain of organic particles to the ocean floor, thus giving the isotope imprint of ocean surface conditions to the bottom dwelling organisms to a large extent. This also favours identical time scales for time series derived by the different types of planktons.

(3) The ^{18}O isotope and ^{13}C carbon isotope variations have to be considered in the context of global mass balances that are of an incomprehensible character. This opinion is well illustrated by Vostok data of ^{18}O of enclosed air and of ^{18}O in ice showing quite different spectral characteristics. The carbonate dissolution study by Farrel et al., (1989) constitutes strong evidence.

(4) The ^{18}O isotope variations in Devils Hole is stated to be induced by atmospheric-water surface interaction (CO_2 -water) in the first place meaning that there is no time delay caused by the long transport of ground water to Devils Hole. The time series constitute primarily a proxy of NH atmospheric conditions.

The primary conclusions and statements are as follows:

(1) It is stated that long term terrestrial surface temperature is a function of total atmospheric mass variations since Archean times.

(2) It is stated that the terrestrial storage of solar energy is dominated by sensible heat in SH ocean as a function of land-ocean distribution and physics governing the terrestrial infrared emission. One conclusion is, that this imbalance causes the continuous warm surface water transfer from SH to NH regardless of climate regime.

(3) It is concluded that the quasi 100 ky cycle originates in NH continental areas as a function of changing infrared emission to space.

(4) The hemispheric asymmetry of both storage of solar insolation (dominates in SH) and of infrared emission (dominates in NH) are concluded to constitute a theoretical basis in explaining a 100 ky forcing from eccentricity variations, despite the fact that the mean yearly hemispherical insolation is almost independent of eccentricity variations.

(5) The global distribution, of the quasi 100 ky cycle in ^{18}O isotope data in all oceans, is concluded to depend on the isotopic imprint given to the global warm water surface current before its final cooling in the North Atlantic and the GIN

sea. This cyclicity is concluded to be transferred from variations in terrestrial infrared emission inducing the same cyclicity in NH mean surface wind speed and in the ocean surface waters.

(6) Horizontal density forcing is stated to be the major force, driving fluid circulation systems on Earth. The force is proportional to density differences in a fluid on a constant potential surface, proportional to Earth angular velocity and is zero at the poles and at the equator and reaches its maximum at 45° latitude.

(7) The major amount of atmospherically bound energy redistribution on Earth, is concluded to occur via subsidence, on hemispheric and regional scales.

(8) The main part of subsidence energy reaching NH from SH is concluded to primarily originate from the circumpolar current area, entering NH at high elevation and descend in NH with a surplus of energy. The process is partially forced by the motion of MPH:s.

(9) The northern interhemispheric subsidence effect (NISE) is stated to cause the well known Dansgaard-Oeschger events, registered in Greenland ¹⁸O isotope records.

(10) Intermittent releases of cold bottom and intermediate NH Atlantic Ocean water into SH Atlantic Ocean, replaced by warm SH Atlantic Ocean water is stated to be the cause of deglaciations in NH. The prime forcing agent is stated to be HDF. Smaller pulses of the same type is concluded to cause Heinrich events.

(11) It is concluded that tidal effects induce circulation system in both the atmosphere and the oceans and that this influence is a major factor in both QBO and ENSO.

(12) QBO and ENSO are stated to be caused partially by interplanetary tidal effects.

(13) The turning on of NISE and the intermittent NH/SH interchange of water are both stated to be controlled by tidal effects.

It is just a hope that climate will get easier to comprehend after these conclusions and statements. It will still constitute an incomprehensible system, that will challenge the skills of scientists for a long time in the future.

3. Answer to the climate change problem

To make it simple, the answer is no. To be more specific, Long term climate change can be explained by variations in the atmospheric mass. There are strong reasons to claim that the overwhelming part of energy involved in the climate system originates from the Sun. There is also strong evidence that climate change will occur assuming a Sun that produces a constant solar effect. Furthermore, energy storage in the oceans of Earth is governed by the Milankovitch variables in both hemispheres. This should mean that climate change problems are not in the first place related to (1) changes in solar energy production or (2) solar insolation variations caused by Milankovitch variables. Two physical processes have been identified that relocate energy on Earth based on known physical principles. The climate change problem is at least partially produced by unidentified processes that initiate relocations of stored energy on Earth.

The critical questions in the climat change problem could be:

- What factors controls the relocations of stored energy in the climate system?
- What factors control the infrared emission to space?

The relocation of stored energy in the climate system might be coupled with extraterrestrial variables. In this respect it will here be stated that the climate change problem can not be solved by processes relating to Earth alone and not either with the action of known tidal effects from the Moon and the Sun. This is why the answer is no. The climate of Earth is still an incomprehensible system.

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Appendix

Appendix 1

Analysis of sunspot cycle phase variations – based on D. Justin Schove's proxy data.
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CHAPTER 47

Analysis of Sunspot Cycle Phase Variations—Based on D. Justin Schove's Proxy Data

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ABSTRACT: D. Justin Schove performed a tremendous work establishing a proxy data set regarding sunspot intensity and phase variations. The data set spans the time from 649 BC–1990 AD and its major part is produced within the "Spectrum of Time" project in which historical data regarding aurorae borealis are transferred to approximative sunspot numbers and sunspot phase information. However, the quality of Schove's sunspot proxy data has been questioned and for that reason has not been used by most modern scientists in their analytical work. In this paper signal processing is used as a tool for evaluating the quality of Schove's proxy data set regarding sunspot cycle phase and length. The analysis is limited to 300 BC–1990 AD for reason of partial lack of data in the excluded period. Only the sunspot cycle phase and sunspot cycle length variations will be considered since these variables are better known than the proxy sunspot intensity for old data. The quality of Schove's proxy data set will be discussed using two evaluation methods. The quality aspect is essential for allowing scientists from different disciplines to evaluate a number of solar-terrestrial connections during a period of more than two millennia. This aspect has certainly been accentuated by recent findings coupling sunspot cycle length variations with global temperature variations.

INTRODUCTION

It is almost 40 years since Schove's sunspot proxy data set was first published (SCHOVE, 1955) although the data which is analysed here is taken from "Sunspot Cycles", edited by D. Justin Schove 1983. The information which is essential for understanding the analysis in this paper is basically very simple. The sunspot cycle length is either the time period between successive maxima in the approximately 11.1 year long sunspot intensity cycle or between successive minima in the same cycle. The sunspot cycle phase (or remainder as Schove calls it) is the integrated deviation from an assumed constant sunspot cycle length. The suitable unit to measure sunspot cycle length is "year" and thus the sunspot cycle phase is measured in the same unit. In Schove's proxy data set the sunspot cycle phase is based on both maxima and minima according to Figure 1. Since the sunspot cycle phase is known exactly since 1750 via direct observation of the Sun, Schove's contribution to science regarding sunspot cycle phase data is to expand it from a period of 230 years to around 2,300 years or from two time series of 21 elements each to two series of 206 elements each. That is a tenfold increase which is of great value, provided that the proxy data is qualitatively acceptable.

It is suitable to analyse time series using signal processing as a tool. The effectiveness of that tool is vitally dependent on the number of elements in the time series. Signal analysis is generally used to describe the variations, to decide their type and to express them in terms of statistical parameters. This is often done, assuming that the variations can be described by a sum of sine curves to which noise has often been added. Schove has assumed that there exists a constant sunspot cycle length (11 $\frac{1}{4}$ yr). His "re-

mainder" (phase) is a description of variations based on that assumption which has not been proven. A constant solar cycle length might not exist at all. The result of the signal processing here is thus based on the same unproven assumption; which should be kept in mind.

This analysis will only deal with the variations in the solar cycle phase and length. The maximum phase changes during the whole period considered here is 14.5 years for phase relating to solar maxima and 10.5 years relating to solar minima. Thus, during 2,300 years the sunspot cycle has occurred up to one cycle early (or late) relative to a cycle with an assumed constant length. The extreme phase values mostly depend on a very slow variation (> 1,500 years), and as far as the author knows it has not been discussed earlier. COLE (1973) dismissed this variation in his signal analysis of Schove's sunspot phase data. The physical implications of its existence are very intriguing.

The main purpose of this analysis will be to check the quality of Schove's proxy data set by using two separate methods. One looks for similar spectral patterns, analysing parts of the whole time series. Hopefully the same pattern will show up in data from old and modern times. The other method is designed to check how sensitive these spectral patterns are when adding simulated noise to the basic proxy data set. The basic concepts in this paper have earlier been presented at the IAGA conference in Buenos Aires (JELBRING and MÖRNER, 1993).

SOME FACTS RELATING TO SIGNAL PROCESSING

Many different signal processing methods have been applied in this work but it is not the intention to explain or describe them here. Still, several facts are critical for the

Basic data

Year of max.	Probable error	Remainder	Min.	Rem.
(-293)	4	9	(-298)	2
(-283)	4	8	(-288)	1
-272	3	6	-277	1
(-261)	4	6	-266	1
(-249)	4	7	(-254)	2
-236	3	9	-243	3
-223	3	11	-230	4
-214	2	9	-219	4
-205	2	7	-210	2

Figure 1.a. Ancient records.

Year of max.	Probable error	Remainder	Min.	Rem.
1705.5	1	5.0	1698.0	-1.5/-2.5
1718.2	1	6.7	1712.0	+0.5
1727.5	1	5.0	1723.5	+1.0
1738.7	1	5.2	1734.0	+0.5
1750.3	..	5.8	1745.0	+0.5
1761.5	..	6.0	1755.2	-0.3
1769.7	..	3.2	1766.5	0
1775.4	..	+0.9	1775.5	-2.0
1785.1	..	-0.4	1784.7	-3.8

Figure 1.b. Modern records.

understanding of the results, and some will be summarized below.

Consecutive elements in Schöve's sunspot phase series are spaced in time between 8 and 17 years. The spacing between samples can be made equidistant (1 year) by an interpolation method so that conventional power spectra can be calculated properly. By doing so, the two time series are expanded to 2,277 elements each. This manipulation of the data set will not affect the frequency limits of spectra. Variations with periods longer than about 22 years, which is decided by twice the average sampling period of independent samples, can be calculated and described.

Each one of the interpolated sunspot phase series can be used by itself for producing power spectra. After checking these, it turned out beneficial to calculate power spectra from the cross correlation of the two time series. The purpose is to limit the influence of random errors in Schöve's series, due to his estimate of maxima and minima. In this way all phase information is used for the spectral analyses and the estimated maximal error in spectral information is kept low.

There is an important consequence based on mathematics which concerns spectra from sunspot cycle phase series and length series. One of the series can easily be derived from the other one by a "derivation" or alternatively and "integration". Thus a Fourier transform of the sunspot cycle length series can be achieved by multiplying each term in the Fourier transform of the sunspot cycle phase series with its individual angular frequency. This means that amplitudes of the components with higher frequencies will be magnified for the sunspot cycle length power spectra relative to the sunspot cycle phase power spectra. The importance of this mathematical law is that

all significant cycles from both types of spectra have to be considered as equally important when trying to understand the physical cause creating sunspot phase and length variations.

DESCRIPTION OF THE SUNSPOT PHASE AND LENGTH VARIATIONS

The basic data set is extracted from "Sunspot Cycles". Figure 1.a and 1.b show small parts of the two basic time series. Schöve's own estimates of maximal individual errors are expressed in the unit of years in one column. Notice that these errors are large for the oldest values and are considered as nil for data after the year 1750, when direct observations of sunspots became organized in a scientific way.

In Figure 2 the concepts of sunspot length and phase are explained as well as the relationship between them. From historical records and the interpretation of them, Schöve estimated which year was the most plausible for hosting a sunspot maximum or minimum. The sunspot cycle length, thus defined, is shown as a function of date in Figure 3. As can be seen, the variations in sunspot cycle length is greater between maxima than between minima. For both series the amplitudes of the variations in sunspot cycle length are greater during the last 700 years than during the earlier period. Probably some of these differences are due to errors when deciding the years of maxima and minima. If such an assumption is right it does not necessarily mean that the spectral structure has to change much because of that reason.

Schöve used the information in Figure 3 to construct his remainders or the sunspot cycle phase according to Figure 2. The result is shown in Figure 4, where the original 206 values have been interpolated and expanded to 2,277 yearly values. As can be seen, the main features in the two time

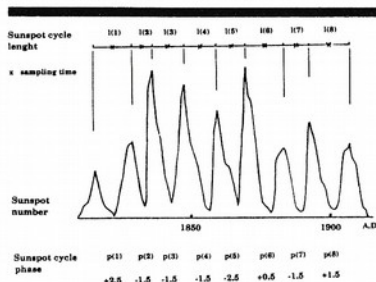


Figure 2. Definition of sunspot cycle length and phase.

series (yearly values) in Figure 4 are very similar, which ensures that also the main features in their spectra are quite similar. From Figure 4 it is clear that there is a strong and slow variation of the phase in both time series.

THE DOMINATING SPECTRAL COMPONENTS

The procedure to expand the two time series and make the samples equidistant and to use information from both

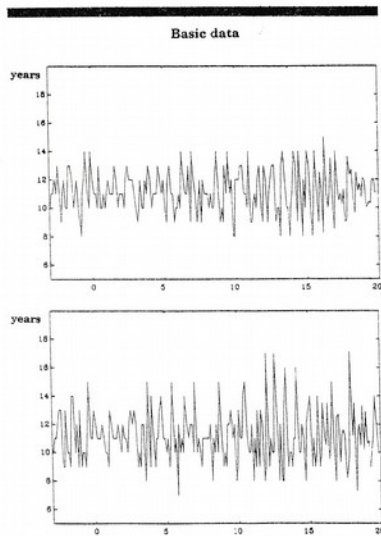


Figure 3 top. Sunspot cycle length between minima.
Figure 3 bottom. Sunspot cycle length between maxima.

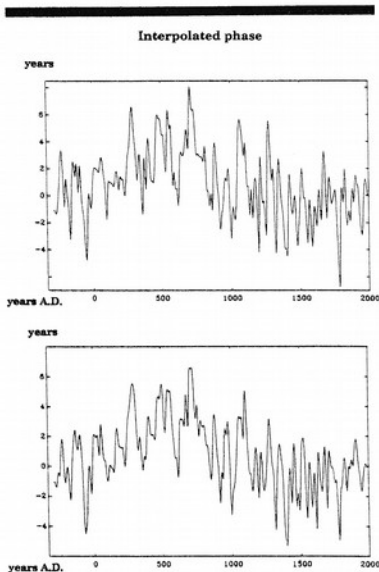


Figure 4 top. Sunspot cycle phase between maxima.
Figure 4 bottom. Sunspot cycle phase between minima.

of them when calculating the power spectra makes it possible to extract significant components with higher frequencies than what has commonly been of interest to scientists. This fact is clearly shown, if the power spectrum of the sunspot cycle length is directly calculated (see Figure 6).

The resolution of spectra will be better the more independent samples there are in the time series. The power spectrum of the two full and expanded phase time series are shown in Figure 5.a. As can be seen, this power spectrum is dominated by a slowly varying component with a "period" around 1,700 years. Dismissing this dominating spectral component and magnifying the rest of the power spectra (Figure 5.b) will reveal the most recognized cycles in the literature, the 200 year and the 79 year cycle.

The power spectra, based on the full sunspot cycle length information, show the same spectral components as in Figure 5.b but with a frequency dependent magnification. As can be seen in Figure 6 the 79 year component is dominating together with a 42 and a 50 year component. The periods for other significant spectral components are also labelled in the figure.

There is no logical reason why spectral components orig-

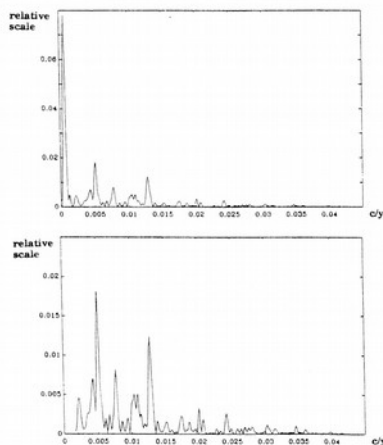


Figure 5a. Power spectrum of sunspot cycle phase.

Figure 5b. Magnified part of power spectrum.

inating from sunspot cycle phase or length should be favoured, when seeking the physical cause of the sunspot generating process. The true solution has to include the whole range of significant components, that is if Schöve's proxy data set is reliable. If any specific component should be pointed out to be more important than any other, it is the slowly varying one with a "period" around 1,700 years. Regarding this component Schöve's data can hardly be wrong. The physical importance of sunspot length variations has been emphasized by correlating extremely

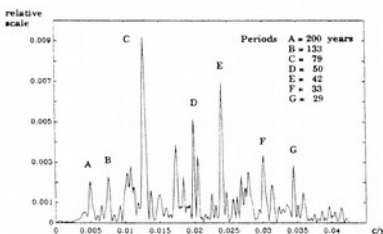


Figure 6. Power spectrum of sunspot cycle length.

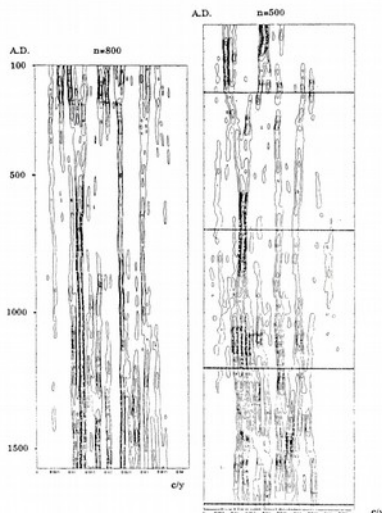


Figure 7. Contours of power spectra.

well with slow temperature variations over the continents in the northern hemisphere (FRIIS-CHRISTENSEN and LASSEN, 1993).

THE QUALITY BASED ON SPECTRAL CONSISTENCY

The spectral characteristics in Figure 6 is calculated using the whole basic data set regarding sunspot cycle length. A way to check if Schöve's data set is reliable is to see if the same spectral components will show up when performing analyses of subsets of the 2,277 elements where the power spectra will be achieved in the same manner as have been described above. By choosing 500 and 800 consecutive samples which have been successively moved two years, Figure 7 has been produced. The picture on the left hand side is a contour made up by 1,477 power spectra and the one on the right hand side contains 1,777 power spectra. The frequency of the components is shown along the abscissa and the time for the central element in each subset is shown along the ordinate while the amplitudes of the spectral components point towards the reader.

Looking at the spectral structures from subsets covering 500 years, it is obvious that they are time varying although some components have a rather stable frequency. This is particularly true for the components with periods of 79 and 42 years. Power spectra that are separated by a sector

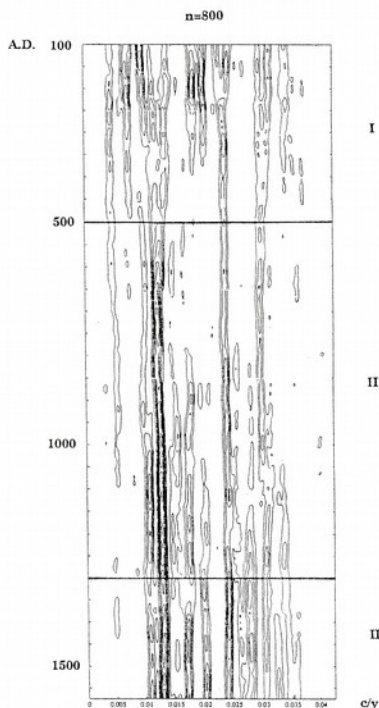


Figure 8. Contours of power spectra.

of at least the size indicated in the right hand side of Figure 7 is produced by independent prime data.

The consistency of the spectral structure is highly increased, if subsets covering 800 years are used for producing the contours as is shown in the left hand side of Figure 7. Figure 8 is a magnification of that figure. Contours in sector I and III are produced by independent prime data. Since nearly the same spectral components dominate in both sector I and III, the spectral consistency between old and modern sunspot cycle length spectra is remarkable. Schove can be suspected to bias (subconsciously) his information regarding for example the 200 year cycle, but hardly regarding cycles with periods he was not aware of when constructing the proxy data set such as the 42-year component.

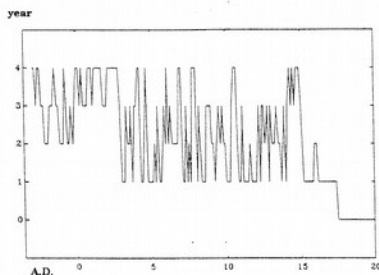


Figure 9. Schove's error estimation.

THE QUALITY BASED ON RESISTANCE TOWARDS DISTURBANCE

Schove had a rather pessimistic view about the quality of his own data. By estimating the uncertainty of each individual year of a sunspot maximum or of a minimum,

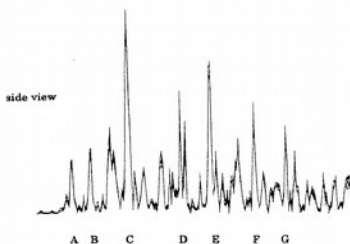
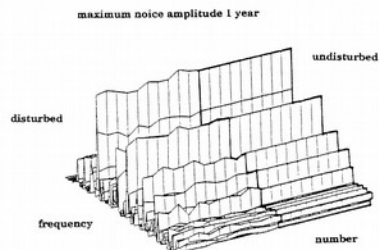


Figure 10. Result of simulations.

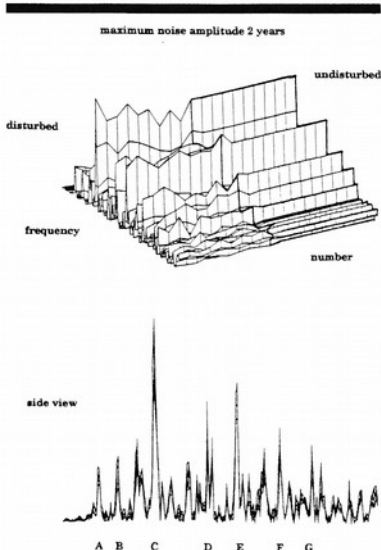


Figure 11. Result of simulations.

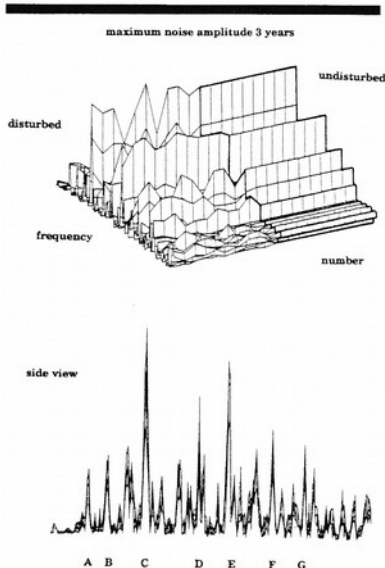


Figure 12. Result of simulations.

he underestimated the quality of the whole data set as such. Furthermore, he did not specify the criteria which he used for estimating the errors (see Figure 9). These are likely to be the maximum possible errors according to Schöve's own unspecified judgment. Schöve's errors should be random and fairly equally distributed during a specific time period, for example 2 or 3 years. We can check the resistance towards such errors by simulating a rectangularly distributed noise on top of Schöve's proxy data set 300 BC–1990 AD. After that we can produce the power spectra a number of times to realize if and how often the spectral structure breaks down.

In Figures 10–12 a rectangularly distributed noise is added to the basic proxy data set (sunspot cycle length series). After that the noise with maximum amplitudes of 1, 2 and 3 years were added, and the power spectra were simulated 10 times for each amplitude. In the upper part of the figures a 3-dimensional picture is shown, containing 10 undisturbed spectra and 10 simulations. In the lower part of the figures a side view of the disturbed spectral components is shown. As can be seen, a noise with a maximum amplitude of 1 year hardly affects the spectral structure at all. A noise with a maximum amplitude of 3 years does affect the amplitudes of the spectral components to a considerable extent, but the spectral structure is fairly unaffected. The capital letters identify the same components as are

shown in Figure 6 and 8. Figures 11–12 show that the spectral structure derived from the basic data set resists the influence from an added realistic noise disturbance quite well.

CONCLUSIONS

(1) Schöve's proxy data set is found to be of a high quality concerning sunspot cycle length and phase information. It should be used as a good substitute for directly observed data of that type at least 2,200 years back in time.

(2) The existence of high amplitude component of slowly varying phase according to Figure 5.a raises the question if there actually exists any physical production process with a constant frequency causing the sunspot cycle intensity variations.

(3) The physical process or processes involved in producing sunspot cycles not only have to produce the assumed 11.1 year intensity cycle, they have to produce a range of structured phase cycles for which the amplitudes seem very time dependent (see Figure 6).

(4) Some time dependent frequency components seem to dominate more, the longer time intervals that are analysed. This feature points to a time dependent statistics. Such systems are very hard or impossible to describe theoretically.

(5) Schove's sunspot cycle proxy data should be taken seriously by many scientists who work with geophysical, meteorological, astronomical, oceanographic and biological time series spanning the last few millennia.

The explanation of the sunspot generating process will demand an intra-disciplinary approach where peak efforts from the whole scientific community might be needed. A good background information about this complex issue is for instance presented by HERMAN and GOLDBERG (1978) and by FAIRBRIDGE and SANDERS (1987). Hopefully this paper will help solve this important problem, which has been obvious to science since Galileo Galilei first observed and described sunspots almost 400 years ago.

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their courage to economically support my work including this study.

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Appendix 2

Analysis of regional palaeotemperature variations.
Paläoklimaforschung 23, 163-176 (1998).

Analysis of regional palaeotemperature variations

Hans R. Jelbring

Summary

GUIOT (1992), and SERRE-BACHET & GUIOT (1987) have calculated the mean annual temperature anomalies for twenty time series associated with 20 meteorological grid-points. The data set covers a time period from 1068-1979 and an area including most of western and middle Europe and the northwestern parts of Africa (see Fig. 1). In this paper the data set is accepted without questioning the quality of the data. Variations in yearly temperature anomalies should by definition show variations that are not mainly caused by specific local geographical factors or seasonal factors. The emphasis here has been to quantify the temperature variations as a function of space, time, and frequency. The approach is mainly considered to search for and to describe important non-random variations in the data set and to produce evolved information. Finding these types of variations, it is important to identify the physical processes causing them. Two particular types of non-random variations have been found. One involves a highly significant out of phase relationship of long-term temperature variation between northern Europe and northwestern Africa along the Greenwich meridian, which might be important when evaluating the so-called "greenhouse effect". The other one concerns highly significant in-phase variations north (Frankfurt) and south (Sardinia) of the Alps. The physical processes causing these correlated variations should be identified by extended analyses.

Zusammenfassung

GUIOT (1992) und SERRE-BACHET & GUIOT (1987) haben die Jahresmittelwerte der Temperaturanomalien für zwanzig meteorologische Gitterpunkte berechnet. Die Datenreihe umfaßt die Periode 1068-1979 und ein Gebiet, das Mitteleuropa und das nordwestliche Afrika einschließt (Fig. 1). In diesem Beitrag wird die Datenbank akzeptiert, ohne die Qualität der Daten in Frage zu stellen. Die Schwankungen der jährlichen Temperaturanomalien sind *per definitionem* nicht von örtlichen und saisonalen Verhältnissen abhängig. Das Augenmerk lag auf einer Quantifizierung der Temperaturanomalien als einer Funktion von Raum, Zeit und Frequenz. Diese Methode wurde gewählt, um nicht-stochastische Schwankungen in der Datenbank zu finden und diese zu beschreiben. Falls es solche Schwankungen gibt, ist es wichtig, die dahinterstehenden physikalischen Prozesse zu identifizieren. Es wurden vor allem zwei verschiedene nicht-stochastische Temperaturschwankungen gefunden. Eine von diesen zeigt eine stark negative Kreuzkorrelation langperiodischer Temperaturschwankun-

gen im Vergleich zwischen Nordeuropa und dem nordwestlichen Afrika längs des Greenwich-Meridians. Die andere zeigt eine sehr stark positive Kreuz-Korrelation zwischen Gebieten nördlich (Frankfurt) und südlich (Sardinien) der Alpen. Die physikalischen Prozesse, die diese Korrelationen verursachen, sollten durch weitere Analysen bestimmt werden.

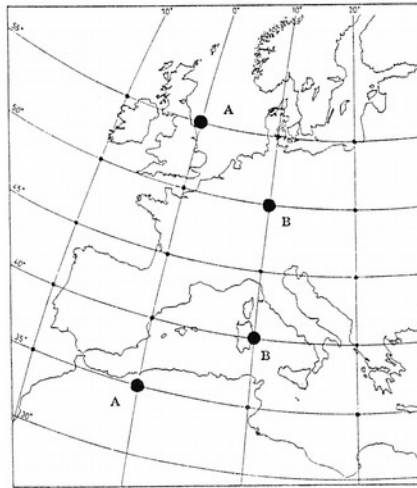


Fig. 1 Grid-points for basic proxy data set. A-A and B-B point out special pairs of locations

1. Introduction

The reasons for climatic changes have been discussed for centuries. Depending on the time span for the considered variations many causes have been proposed and identified. Variations in solar energy output and in celestial parameters, cloud cover variations, variable dust content in the stratosphere, and albedo variations all belong to the causes that are fairly easy to understand but which might not be so easy to quantify, measure or calculate. Another group of reasons are neither easy to understand nor easy to measure. To this group belong all existing cross correlations between solar activity and terrestrial climate (FAIRBRIDGE, 1983), correlations between terrestrial magnetic activity and climate (MÖRNER, 1993), time variable accumulations of atmospheric masses at the poles and equator, and, last but not least, the famous "greenhouse" effect.

It is quite clear that the mechanisms deciding the climate on earth are complicated and not fully understood by the scientific community. At the same time there is conclusive evi-

dence of large historical changes in the climate. Some of these are really spectacular, like the former green period in Sahara and the Arabic peninsula during Mid-Holocene. The documentation of old river structures in these areas using of radar provide striking facts. Of course, there must be physical reasons for such climatic changes, but scientifically binding arguments pin-pointing specific climatic generators are lacking. In this perspective, it might be an advantageous approach to investigate the Guiot data set without the bias of trying to prove or disprove a specific theoretical model. The data is excellently arranged for the use of signal processing technique. By doing so, new facts are expected to emerge, increasing the chances of understanding the climate producing mechanisms.

2. The basic data set and signal processing

GUIOT (1992), and SERRE-BACHET & GUIOT (1987) have presented the sources of their data set. It comes mainly from tree ring series and historical archives, lately combined with instrumental data. Oaks have been used in Germany, Ireland, and Scotland, pines in Italy and France, larches in the French Alps, and cedars in Morocco. Data from historical archives consist of a large number of sources with very varying origin, e.g. summer temperature index based on the German and French grape harvest, central England temperature, beginning of the grape harvest in Switzerland, and frequency of south-westerly surface winds in England. Isotope data from Greenland has also been used. Information, like the above mentioned, constitutes the foundation from which 20 time series spanning the period 1068-1979 have been constructed, expressing proxy values of the annual mean temperature anomaly (see part of this set in Fig. 2).

Signal processing is used as a tool in this paper and the objectives of its use is directed towards the purposes of graphic presentation, calculation of variances of the signals, calculation of crosscorrelation coefficients (CC), calculation of the significance levels of CCs and filtering of signals using MA (moving average) filters. Thus, all the signal processing in this paper is of a standard signal processing type.

3. The objectives for the extraction of information

The main objectives for using signal processing as a tool can be stated as:

- a) To obtain a description of the variations in the data set in such a way that the physical causes of different types of variations might be identified.
- b) To obtain a quantitative description of the variations in the data set for making it possible to rank different types of variations.
- c) To evaluate the significance levels of crosscorrelations.
- d) To identify specific physical subsystems based on the information a-c, if possible.

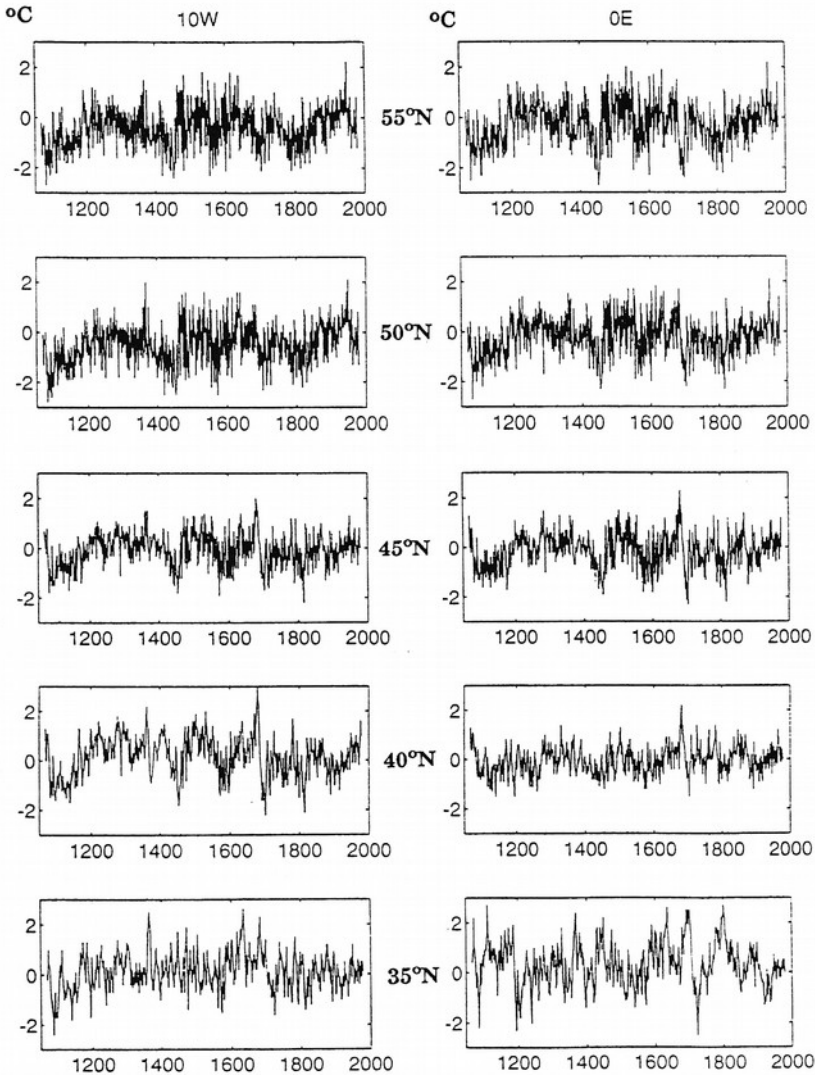


Fig. 2 Basic proxy series of annual mean temperature (period 1068-1979)

The main point of this approach is actually to see if there is something new to discover in the non-seasonal behaviour of our temperature record over a large area and a long time period. Guiot's data set expands the instrumental data set with a factor of four. Since the physical processes in the atmospheric circulation system are very complex, it seems in order just describing (quantitatively) how nature works in the first place, with as little bias as possible. Due to space shortage, the presentation of results here will be restricted to what is thought to be the most important ones.

4. Method

To achieve the goals mentioned above, the main strategy will be the use of two quantified variables, namely the variance of time series (which will here be called effect) and cross-correlation between time series from two locations. To further penetrate the data set each time series will be band pass filtered. The effect variable will be described in two or three bands with periods spanning approximately 2-8, 9-24, and 25-912 years or alternatively 2-15 and 16-912 years. Since the sampling period is once a year and the length of the time series span 912 years, this will limit the extremes of the periods to 2 and 912 years. Hopefully such a method will simplify identification and discrimination of different physical processes causing the signal effect.

The crosscorrelation (CC) between two whole time series is a measurement of how much the yearly mean temperature anomalies in one location have in common with the same variable in another location. The CC can vary between -1 and +1. A value close to 0 means that the signals in the two locations have little in common, they are independent of each other. If so, there cannot be a main common physical process generating both time series. To get a quantitative measurement of the significance levels of the CCs, a high number of CCs were simulated (Monte Carlo) for the locations 0W 55N, 0W 35N and 10E 50N, 10E 40N. In the simulations the order of the 912 values in one of the time series was chosen randomly. As can be seen in Figure 3, none of 1000 simulations got a CC with an absolute value above 0.13. This means that a CC with an absolute value above 0.13 is not random at the significance level of 99.9% for the locations mentioned above. The same significance level can be used as an approximation also for CCs between other grid-points. It should be pointed out here that the calculations of the temperature anomalies did introduce a dependence between neighbouring grid-points but this influence is negligible for grid-points that are not neighbours.

Both the effect of signals and CCs can be described as a function of location (20 grid-points) and frequency band. It is feasible to look for patterns in this description. These patterns can then be interpreted more specifically. The effects will be described for all grid-points, but the CCs will only be treated for a selected number of locations due to space limitations. The eye can often catch subtle patterns in time series and it seems appropriate to compare filtered and unfiltered signals by ocular investigations. Looking at Figure 2 it is

obvious for a trained eye to see that there are more high frequency components in the northern latitudes than in the southern. As we will discover, this observation can be quantified using the description of effects for filtered signals.

The methods described above are limited. There are many possibilities to extend the signal analysis presented here. One promising way is to calculate gradients between grid-points to gain information about the origin and destination of cold and heat spells. Another way to gain more knowledge is to discuss in which way extreme variations during certain seasons will affect the results presented here. The latter type of information has been produced for some parts of the time span 1067-1979 (PFISTER, 1983, 1994).

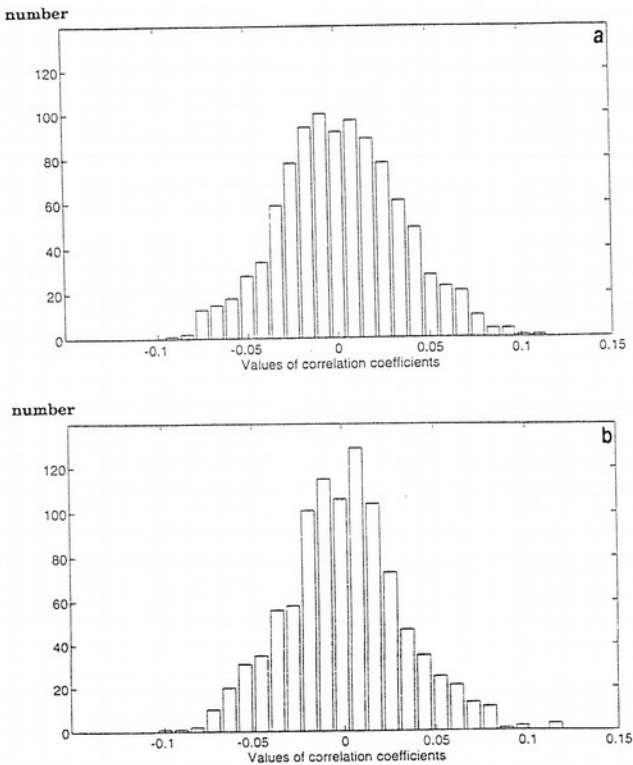


Fig. 3 Histogram of 1000 simulated CC:s at 0E 55N and 0E 35N (a), 10E 50N and 10E 40N (b)

5. Results

5.1 Grid-point effects

The total effects for all 20 grid-points are shown in Figure 4a. The highest value $0.76 (^{\circ}\text{C}^2)$ is found at 0°E 35°N and the lowest $0.24 (^{\circ}\text{C}^2)$ found at 20°E 45°N . The temperature effects as a function of frequency bands are shown in Figure 4b, 5a, and 5b. Observe that a summation of the effects in these figures for each grid-point will approximately produce the effects shown in Figure 4a. The results are quite remarkable. The dominant features in Figure 4a are obviously originating from the slowly varying changes in temperature shown in Figure 4b. The effect differences in the southwestern areas are more pronounced in Figure 4b than in Figure 4a, making them a result of slow variations in temperature. This is confirmed by looking at Figure 5a, where only a tendency is left of that type of effect variations, and in Figure 5b this tendency has disappeared completely. The dominance of faster

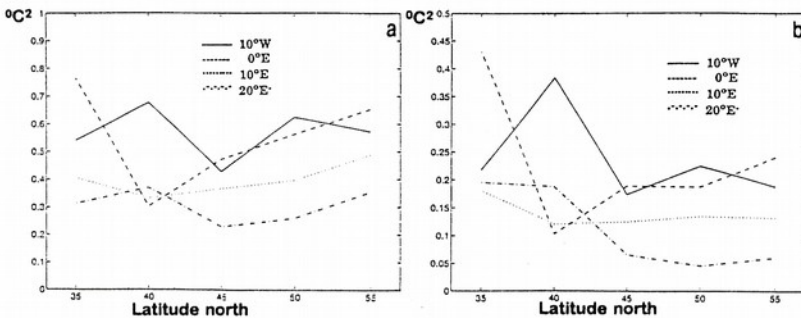


Fig. 4 Total effects for proxy time series 1068-1979 A.D. (a), effects for passband 24-912 years (b)

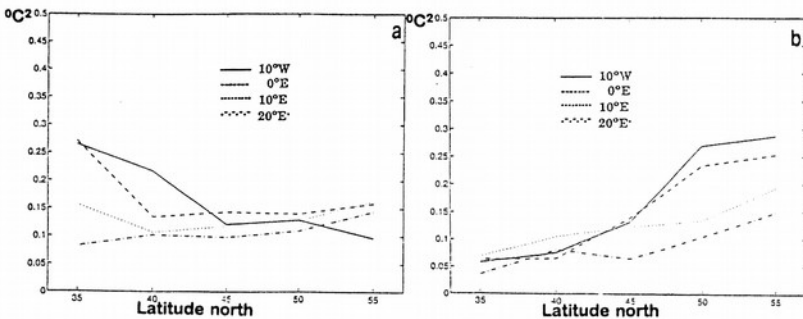


Fig. 5 Effects for passband 8-24 years (a), effects for passband 2-8 years (b)

variations in the northern latitudes and especially in the northwestern areas is quite clear from Figure 5b. The minor effects of fast variations in the southern areas is a general feature. The following characteristics regarding the effect distribution have thus been established:

- a) Quantitatively, most effect is generated by slow variations in temperature, i.e. from variations with periods longer than 24 years. Regionally the peak is reached in southwestern areas.
- b) There is a general tendency for stronger effects in the western parts of the area, regardless of frequency.
- c) Faster variations are bound to northern areas.
- d) The highest regional variations (gradients) of effects occur in the southwestern areas.

5.2 Selected correlation coefficients

Keeping the latitudes constant, the longitudinal distances in Table 1 are around 1300-1800 km and 650-900 km. When the longitudes are kept constant, the distances are approximately 1100 and 2200 km (Table 2).

In Table 1, the CCs are high at high latitudes (45°N-55°N), which most probably relates to variations in the prevailing west winds and the changing rate of mobile polar highs (LEROUX, 1993) at northern latitudes. The negative coefficient at latitude 35°N is remarkable.

In Table 2 the CCs are very different. Most interesting is the negative CC at 0°E 55°N, 0°E 35°N and the high one at 10°E 50°N, 10°E 40°N. The latter is 0.802 when the neighbouring ones are 0.388 and 0.310. This is a riddle. Such a value of a correlation in Table 1 can be mentally accepted because the west winds provide a reasonable explanation based on known physics. The same process can hardly be working between Frankfurt and Sardinia. The Alps should constitute a secure barrier for changes related to temperature advection (moved by winds) between these locations.

The results in Table 1 and 2 indicate that dependences at a significance level of 99.9% between temperature variations in different locations are a rule, at least within the restricted geographical area under consideration. By studying the time series more specifically in some of the locations mentioned above, the reasons for the extreme CCs may appear.

5.3 Special time series

The NW Africa (0°E 35°N) and England (10°E 55°N) time series have been filtered. Parts of the unfiltered and low pass filtered signals are shown in Figures 6a and 6b. Examples of the low pass filtered signals are shown in Figure 6c and of the high pass filtered ones in Figure 6d. The effects (C2) and the CCs for the selected filtered signals are:

Table 1 Selected correlation coefficients relating to 1068-1979 A.D.

Latitude	10°W-20°E	0°E-10°E
55	0.69	0.81
50	0.57	0.95
45	0.50	0.75
40	0.26	0.30
35	-0.22	0.02

Table 2 Selected correlation coefficients relating to 1068-1979 A.D.

Longitude	55°N-35°N	50°N-40°N
10°W	0.39	0.59
0°E	-0.25	0.39
10°E	0.66	0.80
20°E	0.33	0.31

Table 3 Effects and CCs for the England and NW Africa time series

	England	NW Africa	CC
Low pass (period 16-912 years)	0.21	0.35	-0.50
High pass (period 2-15 years)	0.35	0.21	0.02

Table 4 Effects and CCs for the Frankfurt and Sardinia time series

	Frankfurt	Sardinia	CC
Low pass (period 16-912 years)	0.15	0.14	0.84
High pass (period 2-15 years)	0.21	0.16	0.78

Observe that the effects are calculated for whole series but that only parts are presented in the figures for easier perception. The equivalent information concerning the Frankfurt and Sardinia time series are presented in the Figures 7a-7d and in Table 4.

5.4 Reason for the extreme correlations in the selected series

The CCs in Table 3 should be compared with the value of -0.25 in Table 2, and the values in Table 4 should be compared with the value 0.80 in Table 2. The interpretation of the values in Table 3 is that the negative correlation between England and NW Africa is produced mainly by the influence of slowly varying components, since the CC between these locations has become more negative (-0.50), which is shown in Table 3 and Figure 7. The faster varying components from England and NW Africa are practically uncorrelated and they do not contribute so much to the end result (see Figure 6d).

The high, positive CC between the Frankfurt and Sardinia signals is "explained" by the fact that the slowly varying signals are extremely positively correlated, and the same is also true for the fast varying signals. This is shown in Table 4, Figures 7c and 7d. The physical cause for these strong CCs in both frequency bands is, on the other hand, not known.

6. Discussion of the results

6.1 Extent of the analysis

The objective of this paper has been to isolate some important features of the annual mean temperature anomalies in the given set of proxy data which cover the time period 1068-1979. The main criteria to extract these features have been the "effect" of the signals and the CCs between grid-point series. The analyses have not been extended to cover all the grid-points in detail regarding these characteristics. Some series have been examined more closely and they have served as selected examples because of remarkable CCs. The basic data set has thus only been rudimentary analyzed as far as signal processing is concerned. It should be possible to reveal especially interesting facts through detailed analyses of filtered series by analyzing gradients of different variables. Such an investigation could be de

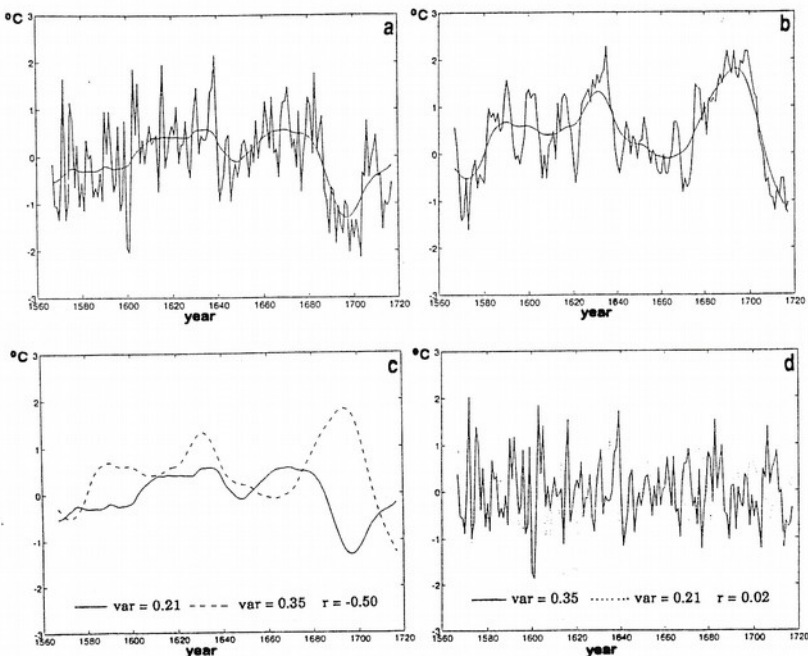


Fig. 6 Parts of unfiltered and low pass filtrated signals of NW Afrika and England time series: (a) OE 55N, (b) OE 35N, (c) OE 55N and OE 35N (low pass filtrated), (d) OE 55N and OE 35 N (high pass filtrated)

signed to test proposals concerning the types of physical generators causing the non-random variations in mean annual temperature anomalies. It could also quantify maximum and minimum effects from a proposed generator. Finally it might isolate influences that have no known physical generators. Such tasks would be possible if the quality of the basic proxy data set is good enough, appears to be a reasonable assumption.

6.2 Conclusions based on the analysis

The following conclusions are based on the results from signal processing of Guiot's proxy data set:

- a) Most (all but one) of the CCs based on 912 samples are not random at a significance level of 99.9%. This implies the existence of several physical generators causing the highly significant CCs.

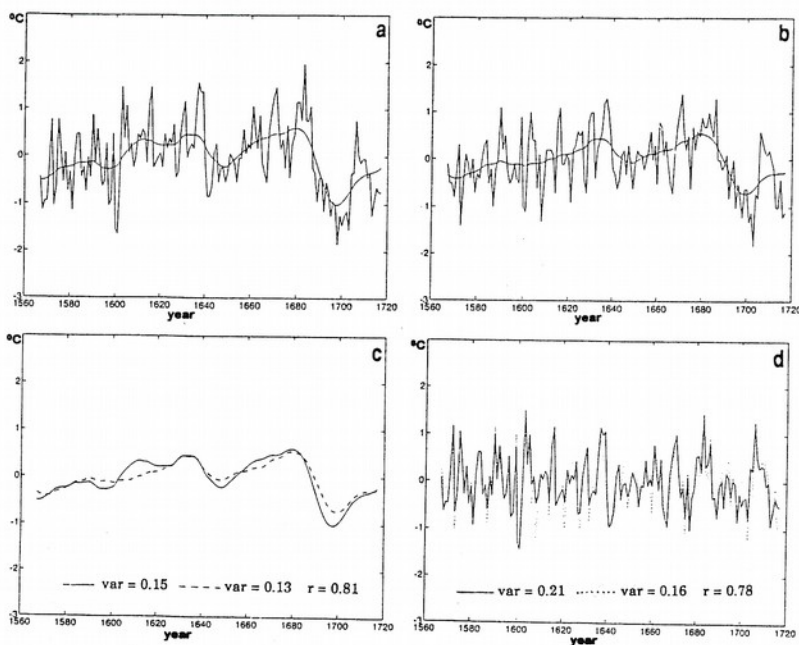


Fig. 7 Parts of unfiltrated and low pass filtrated signals of Frankfurt and Sardinia time series: (a) 10E 50N, (b) 10E 40N, (c) 10E 50N and 10E 40N (low pass filtrated), (d) 10E 50N and 10E 40N (high pass filtrated)

- b) Both effects and CCs are frequency dependent in such a way that different generators seem to dominate in different frequency bands.
- c) The highest CCs are found between close grid-points at the same latitude in the northern areas. It seems as if most of the variations are caused by temperature advection depending on yearly changes in the prevailing west wind system. This type of influences should be possible to quantify.
- d) The very high CCs between the Frankfurt time series and the Sardinian ones are hard to explain by the process of variable temperature advection.
- e) Both effects and signals are functions of location in such a way that the variations in annual mean temperature anomalies are probably produced by several physical generators.
- f) Quantitatively, most effect is produced by slow variations where the period is longer than 24 years and the variations are most pronounced in the southwestern areas.
- g) The second strongest effect is produced by fast variations with periods shorter than 9 years where the effect is almost exclusively generated in northern latitudes and especially in the northwestern areas.

It is not easy to directly suggest the type of physical generators that could produce the annual temperature anomalies with the spectral features and geographical dependencies that have been described.

6.3 Speculations

The results from the rather uncomplicated analyses above are striking in some respects. Consider, for example, the suggested warming of the atmosphere (the last 150 years) which is said to be caused by "greenhouse" gases produced by civilisation. The trend in temperature increase between 1800-1930 is very much like the trend between 1110-1240 in the northern latitudes as is well shown in Figure 8b. Thus, the former can be caused by influences not involving any antropogenic "greenhouse" gases. The whole issue is given another dimension when it is observed that the temperature variations in northern Africa are negatively correlated to the variations in northern or middle Europe (see text and Figure 8b). The carbon dioxide abundance is a truly global atmospheric variable with little local variation, but the "global" warming seems to be local!

It is a fact that the Gulf stream transports energy to Europe and especially northern Europe (MÖRNER, 1994). Changes in the annual mean temperature anomalies can be dependent of the Gulf stream in at least two ways. Changing westerly winds will cause variations, and secondly the route of the Gulf stream might change. The second type of variation is believed to be slow. Thus, the Gulf stream might be the reason why the effect amplitudes are higher in the coastal areas than inland.

The author (JELBRING, 1994) has found evidence for a substantial redistribution of atmospheric energy via subsidence energy, which means that the excess energy during high

pressure situations can be transferred from the inversion level to the ground level. This physical process might be responsible for the negative correlation between northern Europe and NW Africa at the Greenwich longitude and also for the high crosscorrelation coefficients on both sides of the Alps.

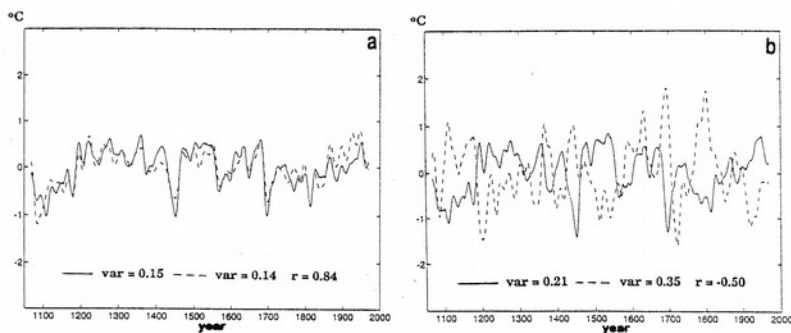


Fig. 8 Low pass filtrated signals of NW Afrika and England at (a) 10E 50N and 10E 40N, (b) 0E 55N and 0E 35N

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Doctoral theses from the P&G unit:

- (1) **Kirittopoulos, P., 1984:** Neogene lacustrine deposits in the inland basins of northern Greece: Stratigraphy, paleoenvironment, paleomagnetism and industrial usefulness. (*Opponent: Prof. I. Hessland*).
- (2) **Sylwan, C., 1989:** Paleomagnetism, paleoclimate and chronology of Late Cenozoic deposits in southern Argentina. (*Opponent: Prof. V. Bucha*).
- (3) **Ruocco, M., 1990:** Paleomagnetic analyses of continental deposits of the last 3 Ma from Argentina: Magnetostratigraphy and fine structures or reversals. (*Opponent: Prof. C. Laj*).
- (4) **Sjöberg, B., 1991:** Magnetic properties of the Limhamn rocks. A paleomagnetic, rock magnetic and paleoenvironmental study of the Maastrichtian chalk and the Danian limestones in Limhamn, Scania, southern Sweden. (*Opponent: Prof. D. H. Tarling*).
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- (9) **Jelbring, H., 1998.** Wind Controlled Climate. (*Opponent: Prof. Gaston R. Demarée*).